2002-09

# Requirements for digitized aircraft spotting (Ouija) board for use on U.S. Navy aircraft carriers

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# NAVAL POSTGRADUATE SCHOOL
# Monterey, California

# THESIS

**REQUIREMENTS FOR DIGITIZED AIRCRAFT SPOTTING (OUIJA) BOARD FOR USE ON U.S. NAVY AIRCRAFT CARRIERS**

by


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Adam Michels


September 2002

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# REPORT DOCUMENTATION PAGE

*Form Approved OMB No. 0704-0188*



| | | |
|---|---|---|
| **1. AGENCY USE ONLY** ***(Leave blank)*** | **2. REPORT DATE** September 2002 | **3. REPORT TYPE AND DATES COVERED** Master's Thesis |

| | |
|---|---|
| **4. TITLE AND SUBTITLE** Requirements For Digitized Aircraft Spotting (Ouija) Board For Use On U.S. Navy Aircraft Carriers | **5. FUNDING NUMBERS** |
| **6. AUTHOR (S)** Timothy Thate and Adam Michels | |
| **7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)** Naval Postgraduate School Monterey, CA 93943-5000 | **8. PERFORMING ORGANIZATION REPORT NUMBER** |
| **9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)** COMNAVAIRLANT | **10. SPONSORING/MONITORING AGENCY REPORT NUMBER** |

**11. SUPPLEMENTARY NOTES** The views expressed in this thesis are those of the author and do not reflect the official policy or position of the U.S. Department of Defense or the U.S. Government.

| | |
|---|---|
| **12a. DISTRIBUTION / AVAILABILITY STATEMENT** Approved for public release; distribution is unlimited. | **12b. DISTRIBUTION CODE** |

**13. ABSTRACT *(maximum 200 words)***

This thesis will evaluate system and process elements to initiate requirements modeling necessary for the next generation Digitized Aircraft Spotting (Ouija) Board for use on U.S. Navy aircraft carriers to track and plan aircraft movement.

The research will examine and evaluate the feasibility and suitability of transforming the existing two-dimensional static board to an electronic, dynamic display that will enhance situational awareness by using sensors and system information from various sources to display a comprehensive operational picture of the current flight and hangar decks aboard aircraft carriers.

The authors will evaluate the current processes and make recommendations on elements the new system would display. These elements include what information is displayed, which external systems feed information to the display, and how intelligent agents could be used to transform the static display to a powerful decision support tool. Optimally, the Aircraft Handler will use this system to effectively manage the Flight and Hangar decks to support the projection of air power from U.S. aircraft carriers.

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|---|---|---|---|
| **14. SUBJECT TERMS** Intelligent Agents, Decision Support, Aircraft Handling, Sensor Fusion, Machine Vision, Network Management | | | **15. NUMBER OF PAGES** 188 |
| | | | **16. PRICE CODE** |
| **17. SECURITY CLASSIFICATION OF REPORT** Unclassified | **18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified | **19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified | **20. LIMITATION OF ABSTRACT** UL |

NSN 7540-01-280-5500 **Standard Form 298 (Rev. 2-89) Prescribed by ANSI Std. 239-18**

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**REQUIREMENTS FOR DIGITIZED**
**AIRCRAFT SPOTTING (OUIJA) BOARD**
**FOR USE ON US NAVY AIRCRAFT CARRIERS**

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**MASTER OF SCIENCE IN INFORMATION SYSTEMS MANAGEMENT**

from the

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## ACKNOWLEDGEMENTS

We thank our sponsors at COMNAVAIRLANT, Mr. Warren Bizub and Commander Dave Shirley, USN for supporting our research. We also thank the Fleet handlers and other Air Operations personnel who took the time and effort to respond to our questions.

We would also extend out appreciation to the folks at Pulnix, National Instruments, Lockheed ATL, and Northrop-Grumman Newport News Shipbuilders.

Lastly, we wholeheartedly thank our families, but especially our wives for their unwavering commitment to us and for the long hours of “solo” parenting while we researched and wrote this thesis.

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## EXECUTIVE SUMMARY

The ability to make effective decisions with limited resources has never been more important. In view of recent asynchronous terrorist attacks on the United States, the ability to rapidly identify a mission, required personnel and critical material will make the difference between mission success and mission failure.

Collaborative tools and environments with the addition of dynamic intelligent agents will be integral to successfully moving against adversaries anywhere in the world as they are revealed.

Establishing a dynamic testing platform where emerging collaborative tools, intelligent agents, and “cutting edge” technology can be effectively and proactively integrated into all facets of flight deck planning and mission execution is logical and necessary.

The primary benefit of a Flight Deck Collaborative Tools and Intelligent Agent Test Bed (or platform) is to provide accurate “requirements modeling” necessary for subsequent research efforts to effectively identify the collaborative tools and intelligent agents to support “Rapid Decisive Operations” in projecting air power.

If the United States strategically plans to use military air power to overwhelm enemies, advanced dynamic collaborative tools and intelligent agents will be of paramount importance.

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# I. INTRODUCTION

**Oui·ja** (wēʹjə, -jē)

A trademark used for a board with the alphabet and other symbols on it, and a planchette that is thought, when touched with the fingers, to move in such a way as to spell out spiritualistic and telepathic messages on the board.

## A. BACKGROUND

In the midst of the “War on Terrorism”, the strategic value of U.S. aircraft cannot be underestimated. The ability to launch and land aircraft independent of an adversary’s defenses and without the use of neighboring countries airfields gives the U.S. government great flexibility in projecting power abroad.

The role of carriers in future conflicts will broaden to provide support for other U.S. military aircraft[1], coalition aircraft, and possibly civilian humanitarian relief aircraft.

The exponential increase in the use of Unmanned Aerial Vehicles (UAV) to include Vertical Take-Off and Landing Tactical UAV (VTUAV) and Tactical Control Systems (TCS), and future programs of the Naval UAV Long Range Plan, such as Naval Multi Role Endurance (MRE) UAV and Naval Unmanned Combat Aerial Vehicle (UCAV-N) will require robust command and control systems that can quickly adapt not only to changing missions, but also to the broadening range of aircraft to be safely launched and recovered at sea.

[1] *Operation Enduring Freedom* was unique in that the USS Kittyhawk deployed *sans the Air Wing* in order to use her as a Special Operations platform

While Army and Air Force fixed wing aircraft are not engineered for landing at sea, the recently awarded contract for Joint Strike Fighter (JSF), an affordable, multi-service aircraft that will replace several different aircraft in service today, could radically increase the number of fixed wing aircraft capable of leveraging the mobile aircraft carrier platform.

Further, the time necessary to respond to a conflict will be critical. From the Office of Naval Research[2];

> War fighters need the ability to strike time-critical tactical, operational, and strategic targets at the right moment in the battle. We therefore aim to help them project power and destroy, neutralize, or suppress targets of immediate importance to them. We are developing technologies that enable strike against targets in compressed vulnerability windows in all joint operations, in any environment, under all conditions. We don’t want the enemy to be able to hide, or flee, or get in the first blow.
>
> Why is this Future Naval Capability important? Our future adversaries aren’t likely to be so obliging as to present themselves as easily detected and classified stationary target arrays. They will be mobile or moving, they will do their best to hide in clutter, and they will be uncomfortably close to friends and neutrals. Our forces will need to deliver strikes with unprecedented accuracy, flexibility, and speed.

In order to operate in “strike time”, it is advantageous to have an integrated command and control systems that will not only display the present location of aircraft, but also facilitate dynamic mission planning and scenario driven solutions for mission execution. All phases of a mission could

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[2] *“A Future Naval Capability: Time Critical Strike”, http://www.onr.navy.mil/onr/media/download/time_critical.pdf, June 7, 2002*

be addressed including staging, maintaining, arming, launching, and recovering of aircraft.

What is the status of the systems that currently support the planning and execution of aircraft handling on U.S. aircraft carriers? Preliminary research indicates that the display used for handling of aircraft on aircraft carriers is static and the process used for planning aircraft spotting is not automated.

Aircraft movement is planned and tracked on paper, on fixed status boards and on the “Ouija” board (Figure 1) that provides a static reference for the orientation, location, and status of aircraft on the flight deck and aircraft in the hanger bays.

Figure 1. The “Ouija Board”

Two-dimensional templates of the specific aircraft are moved about this static table to represent each aircraft’s relative position and orientation. Other symbology is used to represent processes or other maintenance information that change

or impact an aircraft's availability. For example, aircraft are prepared and moved for launch, recovery, re-arming, refueling and if necessary, maintenance. Figure 2 depicts representative symbology used on USS HARRY S. TRUMAN (CVN 75).

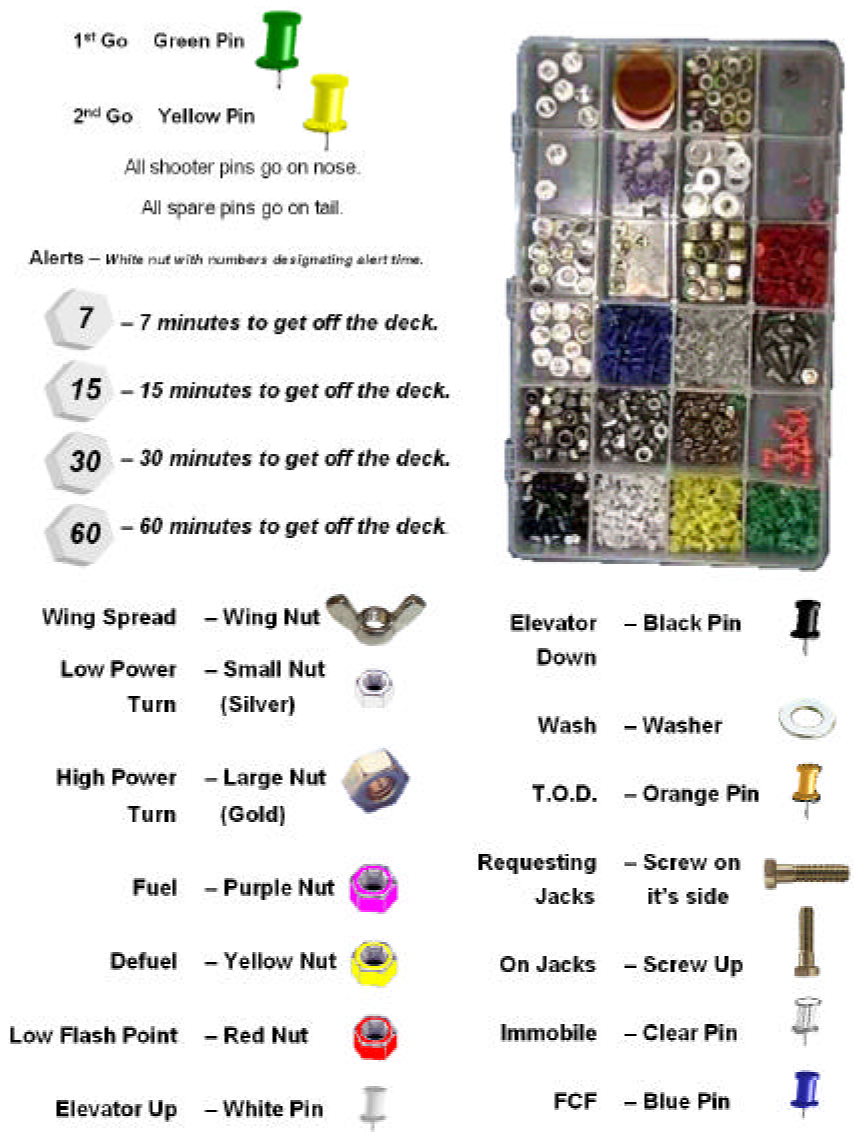


Figure 2. "Nutology" Used Aboard USS Truman

Movement and status of aircraft is collected via sound-powered phones, ships telephone circuits, radio, and messenger. On deck during flight operations, directions for the movement of

the aircraft could be relayed via radio, but is most often communicated via hand signals. Voice communication on deck between handlers and other deck crew is possible in the midst of turning aircraft engines, but a speaker would literally have to yell to each participant individually and depending on the level of environmental noise, the speaker might literally have to put his mouth within inches of the listener’s hearing protection (“Mickey Mouse” ears) to conduct his words effectively as illustrated in Figure 3.

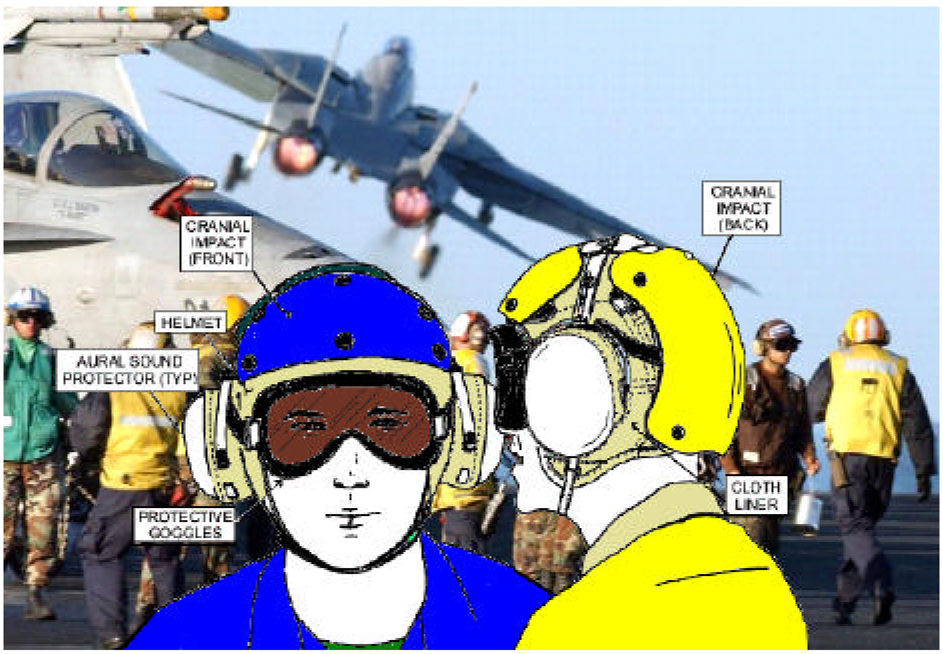


Figure 3. Verbal Communication on the Flight Deck

The present system of handling aircraft using the static table works, but that can primarily be attributed to the diligent expertise of the professional handlers. While the present system works and is highly reliable, the information depicted on the Ouija Board is not readily available anywhere else. In fact, if any other decision makers or planners need

aircraft status, they would either call or physically visit Flight Deck Control where the Ouija board is maintained.

While observing carrier qualifications on USS HARRY S. TRUMAN (CVN 75) from Flight Deck Control, it was obvious that it was the well-seasoned Aviation Boatswains Mates that made flight operations look well orchestrated, smooth, and safe. The reality is that physically moving aircraft on a carrier will always have a high level of risk. The manual system currently used to plan and track aircraft movement is very labor intensive with duplicate data collection and recording processes. This process is primed for a technology infusion. But considering the manual system "works", simply digitizing the existing processes will not be value added. It is our view that a digitized system should automate processes, reduce duplicate tasks, standardize inputs and share information to all assigned stakeholders.

Therefore it is logical that emerging technologies now available, including wearable computers with miniature Heads-Up Displays (HUDs), Personal Digital Assistants (PDAs), and other wireless tools would be integrated into the next aircraft handling display and planning tool.

This system becomes more than the Handler's display, but instead becomes the Situational Awareness display that will allow users to access all of the data stored in the vast array of systems currently in use. These large-scale relational databases are not being used to their greatest potential and require additional consideration in our project.

We feel that the Air Departments' data and knowledge management would benefit greatly from the use of collaborative tools, Agent technology and dynamic Intelligent Agent Systems (IASs). We discuss the use of agents in chapter VI. Software

agents are autonomous programs that are capable of gathering information regarding their environment and are then able to act in accordance to this information. They are in turn able to affect their environment by their actions.

Our system's goals are not only a "real time" depiction of relative aircraft positions, but the use of software agents programmed that take into consideration all operational requirements that will impact planning, maintenance, fueling, de-fueling, arming, launching and recovering aircraft.

Optimally, aircraft movement would be minimized. The Digital Ouija Board can suggest optimized move plans that minimize the movement or re-spotting of aircraft and the deliberate staging of aircraft for movement as required by the complex mission requirements for the current mission sortie and for subsequent sorties. The system would need to quickly assess all of the parameters that are routinely considered whenever re-spots are conducted. This is the ideal use of agents since they can be programmed to check the conditions of all the requirements and compare the outcomes of such queries to other alternatives, and then provide a course of action that has been weighed against all of the possibilities.

Intelligent agents could be used to prompt user interface while considering and tracking individual aircraft characteristics such as dimensions, turning radius, wingspan, jet exhaust and/or rotor wash envelopes and others as appropriate. Other items that agents could manage include maintenance, servicing assets for fueling, power, SINS (Ships Inertial Navigation System) cable, and support equipment (commonly called "yellow gear") location and availability.

The agents could be used, for instance, to validate track identification on the digital display. An agent is “assigned” to monitor the track and the track identification. Should the agent assess the correlation between the reported track and the identification of that track to be less than 80% sure (whatever value is determined to be the minimum threshold), then the agent will react by eliciting another agent that is responsible for determining who on the flight deck is closest to the track in question. Once this information is known, the agent can have a message sent to that individual to have them verify the aircraft identification to a designated operator in Flight Deck Control. This operator then inputs the data and the system is then 100% sure of the tracks identification. This same scenario may cause the agent to respond by instructing a flight deck camera to zoom in of the track in question. This would then provide the operator a video display that he or she can look at to determine the identification of the questionable track.

Specific safety issues that could be addressed by intelligent agents include collision alerts between aircraft and between people and aircraft, object proximity alerts, and damage control and fire fighting (asset location/aircraft fuel loads/aircraft weapons load out).

The system would be able to run in all phases of launch and recovery operations regardless of shipboard power or casualty[3] situations. Therefore, other critical issues that we feel should be emphasized and addressed include system reliability, sustainability, and availability.

[3] A shipboard casualty would be damage incurred from an accident or inflicted by the enemy.

Sustainability and redundancy could be accomplished ideally with synchronized laptop computers in primary workspaces, battery operated wearable computers and Uninterrupted Power Supply (UPS) outfitted servers below deck. An off site redundant server could also be established and synchronized via dedicated data link or data systematically spooled and pushed using available idle bandwidth. For example, the system could push cached or stored data over the data link, but would pause when another system required bandwidth for message traffic, email, video conferencing or other bandwidth intensive application.

Up to date deck configuration and/or deck activity would be readily available on display repeaters at logical places throughout the ship (Bridge, CO's cabin, Command and Control (CIC), Ready Rooms, squadron maintenance control, etc.) and on deck and flight crew PDAs (either via wireless connection or infrared ports).

When a mishap occurs, detailed video information could be extracted from archived "tracks" for aircraft, yellow gear and deck crew for both mishap and the events leading up to the mishap.

A detailed summary of potential stakeholders that would use this system and the necessary intelligent agents that would apply and their functionality and, most importantly, their benefits will include but are not limited to:

- CAG/Ship Information Agents: All of the data will be available throughout the aircraft carrier and conceivably could be shared across the CVBG or even to the theater commander.
- Squadron Information Agents: Locate aircraft prior to manning or maintenance. Remotely "Click" on an aircraft icon to get "real time" status of weapons

load, fuel load, error codes, and maintenance information.

- System Network Monitoring Agents: Intelligent Agents could be used to passively monitor network node connectivity and availability. These nodes will include all the fixed sensors and all mobile PDAs and wearable computers on the flight deck.
- Deck Spotting (“Ouija” Board replacement) Agents. Flight deck and Hangar deck specific programs that optimize capture and record aircraft location and orientation.
- Knowledge Management.

  The system should record meaningful data and assign ownership of that data. Permissions should be established and assigned as to whether a user has read, read/write, delete, or change permissions (need to know). An audit trail detailing who initiated changes to elements of a plan or status of an aircraft should be maintained. For example, a mess specialist on the mess decks should not have the ability to change the readiness of an aircraft. The system should control access. If elements of a plan are needed, the system should prompt the “actor” with an automated email, phone call, page, or 1MC announcement. The intelligent agents will dynamically collect data from all contributors and present scenario driven options for the Aircraft Handling Officer, for example, to select and promptly execute.

  - Operations can program in the flight schedule and the system of cooperative agents can determine the most efficient way to spot aircraft taking into account the real time status and location of the aircraft on the deck. This will also facilitate dynamic placement of aircraft during recovery and sequence aircraft movement to avoid delays or collisions. For example, the system could anticipate a collision and prompt one handler to pause until the threat passed.

Intelligent agents could cooperate on providing passive integration with other systems so, for example, inbound aircraft

characteristics could be automatically assimilated into the system. The agent cooperative intelligence could continually evaluate information system data. Aircraft movement could be optimized though simulation scenarios. The intelligent agent could be running in the background or running in parallel would anticipate conflicts and then generate viable alternatives before conflict was realized. The system would prompt user interaction before problems materialize.

The importance of the placement of aircraft prior to the day's first event is critical to how the carrier battle group is able to effectively execute the air plan. Since the air plan is made up of sequential sorties, all sorties should be considered before the first aircraft is move or re-spotted.

Approximately seventy aircraft make up the current air wing on a carrier. The four and one-half acres of flight deck, plus the hangar deck, are used for launching and recovering aircraft, as well as storage and maintenance of aircraft. Deck space is also needed for loading and unloading, pre-positioning and short-term storage of ordinance. Additionally all of the Air Department's Flight Support Equipment (FSE) is operated, stored and repaired on the flight and hangar decks. The impact is that every square inch of the flight deck and hangar deck is actively used. We feel this use should be optimized and aggressively managed to ensure the fluid ballet of perpetually spotting and re-spotting of aircraft and equipment.

One of the primary goals for the next generation aircraft carrier, CVNX, is that the platform generates *20% more* sorties with the same type and number of aircraft from the same sized flight deck as today's Nimitz class carrier. It has not been specified how this will be accomplished, but it stands to reason

that increased flight deck efficiency could be realized by embracing technology and automating many redundant processes.

The Handler and other key decision makers, Air Operations, for example, will need to have all the appropriate and accurate information at their fingertips in order to realize the efficiency goal. Decision support and process optimization software can aid the handler both in planning and in execution by decreasing the number of re-spots, thus increasing deck efficiency. A comprehensive system of this caliber does not currently exist, but all of the elements required for this system are available either in existing legacy systems or by using available technology. Of note, there is at least one vendor[4] that we have been in contact that has developed a working prototype of such an integrated system, complete with a Digital Ouija Board. This prototype is not a complete working model, but it does prove the concept of how a totally revamped information system could be used to bring all of the data elements together

The formal title for the Handler is the Aircraft Handling Officer (ACHO). The Handler is responsible for movement of aircraft on the Flight Deck and between the Flight and Hangar Decks in preparation for and during flight operations. Specific duties include the following:[5]

- Oversee Organizational Level aircraft maintenance and assure aircraft spots on the Flight and Hangar Decks can expedite the next two launches.

[4] Northrup-Grumman's Newport News Shipbuilding Division has a prototype system, the *CVN AirOps Management Information Systems Demonstrator*

[5] NAVAIR 51-15ABH-1-74 Operation And Maintenance Aviation Data Management And Control System (ADMACS) And Integrated Shipboard Information System (ISIS), section 007, page 4

* Be aware of aircraft and report changes based on aircraft availability.
* Track number of aircraft airborne, on the flight deck, and on the Hangar Deck, along with the weapon types on the Flight and Hangar Decks, and other flight deck equipment availability (i.e. AESS (Auxiliary Equipment Support Stations), Tilley, and fuel pumps).

The current system uses a flat table-sized display board that has the scale outline of the flight deck as shown in Figure 4. The hangar is represented on a separate board that can be pulled out when needed.

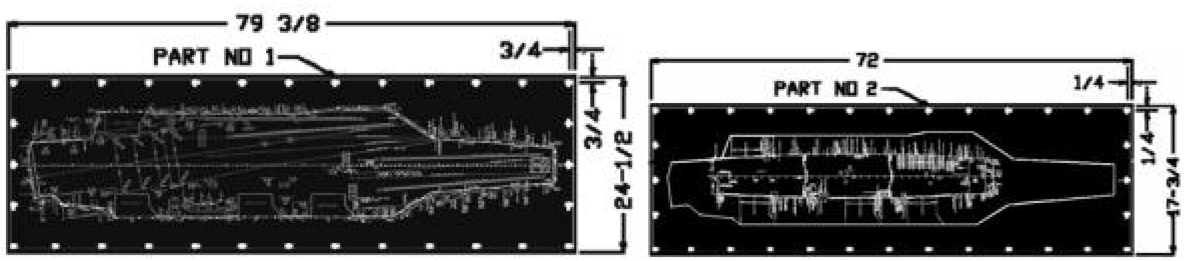


Figure 4. Flight Deck Spotting (Ouija) Board Design

The “Ouija Board”, as it is known, has been used for at least fifty years. Scaled cutout models, or templates, of the aircraft are placed on the board to represent the relative position and orientation of the individual aircraft on the deck. Because the board is used both for planning and operational execution, the presentation may represent either the planned or actual aircraft position. If the representation is accurate, it is only depicting the reported position. This position is derived from by voice reports relayed to a “Blue Shirt” (usually a junior enlisted Aviation Boatswains Mate) phone talker who

receives aircraft position information from a lookout located at a vantage point in the island above the flight deck. Additional information is displayed on the two-dimensional models depicted previously in Figure 4 which will aid the Handler in making decisions. An example of such “nutology” is the use of a wing nut, which signifies an aircraft needing a wingspread. Usually a squadron representative or the CAG representative would let the Handler know of his desires to have a particular aircraft’s wing’s spread, typically for maintenance.

In this sense, the Ouija Board is a rudimentary decision support tool. Due to its size it is not portable, so the information depicted upon it cannot be readily shared with other decision makers. A digital camera could be mounted above the static board and display an image of the table to other spaces, but the benefits of that display would be limited to what was on the table and would not be interactive.

Depending on flight operations and the current location of the aircraft in relation to the flight line, spreading an aircraft’s wings might hinder another aircraft launch or recovery. Instead, the aircraft might be re-spotted or delays spreading the wings until the higher priority operations were completed.

The dominant impression of today’s Ouija Board is that it works not because of technology, but because of the dedicated professionalism and experience of the fleet Handlers. This methodology is very labor intensive and doesn’t allow the organization to share operational knowledge. Technology could be used to reduce redundant tasks and increase operational awareness throughout the organization, not just on the flight deck.

Equally important, there is very little in the way of written procedures or guidance on how to do the Handler's job and how to use the Ouija Board. Rules for the Carrier[6] and the Air Department[7] personnel, as well as Personnel Qualification Standard's[8] exist, but they do not describe how the Handler performs his craft, which has been described as something between "black magic and art" on more than one interview.

There are some obvious shortcomings to the present system. The system is not automated in any way. The depiction of "real time" aircraft movement cannot be captured with any accuracy because of how changes are reported and then how changes are recorded.

Figure 5 depicts the most common "landmarks" or traditionally named areas.

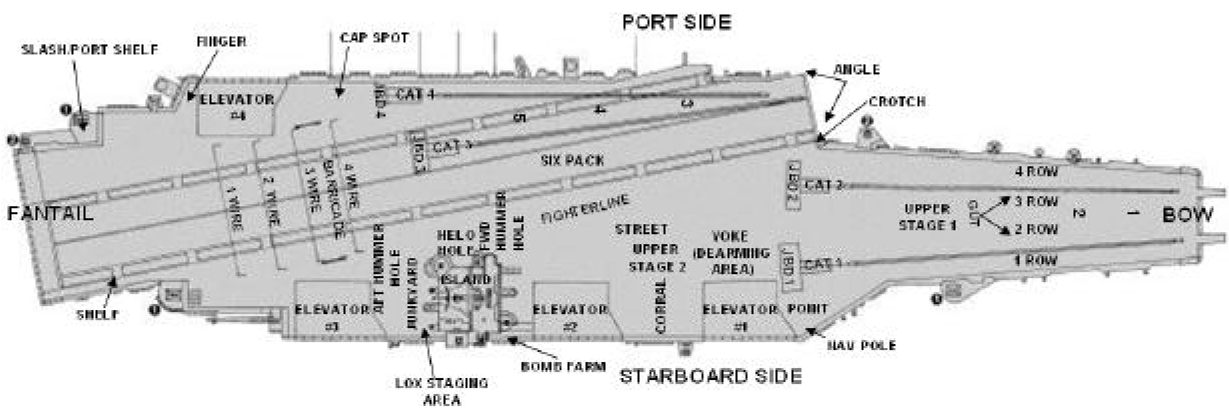


Figure 5. Flight Deck Area Names

For example, a Sailor could report an aircraft's position in gross terms of starboard, port, forward or aft in relation to the island, centerline, fantail (aft most area of the ship), bow

6 NAVAIR 00-80T-105, CV NATOPS Manual

7 NAVAIR 00-80T-120, CV Flight/Hangar Deck NATOPS Manual

8 NAVEDTRA 43426-3 CV/CVN AIR DEPARTMENT OFFICER WATCHSTATIONS

(forward most area of the ship), near one of the ship’s prominent landmarks (i.e. elevator 1 or “L1”), or traditionally named areas including the “six pack”, the “finger”, or another known general area.

The reporting sailor or “phone talker” positioned in the island overlooking the flight deck is not in a vantage point that allows him to observe the entire flight deck simultaneously.

The phone talker in Flight Deck Control will listen to these reports, interpret them, and then simultaneously repeat the report out loud for the benefit of the Handler and either slide or pick up the template to move it to the new position on the Ouija board. Depending on the report, a log entry might also be made.

What can make this reporting process more complicated and less reliable as a planning tool or operational decision support tool is that once a template is lifted from the board, true visibility of that aircraft on the board is lost. Arbitrary placement of the template after it is lifted doesn’t give the Handler the historic placement or visual cues to determine what went wrong or anticipate conflicts based on projected movements of other aircraft in the same area.

During interviews conducted for this thesis, we were told a “sea story” of how the Handler peered out his porthole (window) to see a completely different reality than the one depicted on the board. Being the sharp individual he was, he told the “phone talker” at the table to keep quiet for a moment. When the Handler ascended and arrived at the lookout point where the other phone talker was stationed, he found the other sailor sound asleep. It turned out that the first sailor was covering

for his sleeping buddy by periodically and randomly moving the aircraft templates on the Ouija Board to give the appearance of business as usual.

The current Ouija Board does not serve as a truly “dynamic” display nor can it be considered dynamic as a decision support tool in regards to aircraft movement.

## B. PURPOSE

While there are standard operating procedures for most redundant tasks in the military, in the area of aircraft handling, most processes and methodologies are learned on the job.

The primary purpose of this thesis is to describe the requirements for a system that will display flight and hangar deck information, as well as assisting in the planning and the movement of aircraft on U.S. Aircraft Carriers. It turns out that the Digital Ouija Board is just a portion of a larger issue, that of information visibility. As such, we will include requirements that could be used for the carrier’s air departments’ information and knowledge management.

Because of the complexity of handling aircraft in an operational environment, this thesis will serve as an introduction and general overview of the collective processes, ongoing systems improvement efforts, and will recommend the systems architecture solution and associated methodology that could be developed and implemented.

Emerging and available technologies can be used to improve operational efficiency and effectiveness, but the organization must first understand how information is used in its business

processes and then how it applies to fulfilling mission requirements.

The movement of aircraft is currently displayed on a static table. The value of the information held on this table is limited in terms of Command and Control because the templates used on the Ouija Board can only display where things currently are or where things should be. Information in this physical format cannot be easily communicated, manipulated, nor updated.

Donald K. Krecker and David C. Knox from Martin Marietta Laboratories and John B. Gilmer, Jr. from Wilkes University stated,

> Command decisions are based on static knowledge, including doctrine, tactics and experience, plus dynamic knowledge of how the battlefield situation is evolving. The static knowledge informs a command post's intelligence, planning, and current operations functions, while the dynamic understanding of the situation is both an input and output of these activities.

In order to increase the abilities of the personnel who routinely depend on the Ouija Board for situational awareness, it would be completely remiss not to include a dynamic display and an integrated knowledge base. This will allow users to drill down on a particular item of interest or to be alerted to an impending problem. Current carrier personnel agree that it would also incorporate elements that propose solutions to known problems and have the ability to “learn” as new issues arise.

The advantage of adding a dynamic aspect to any display may seem intuitive. Studies have attempted to quantify the advantages and depict the knowledge gained by doing so. The illustration in Figure 6 depicts what the user gleans from a static display.

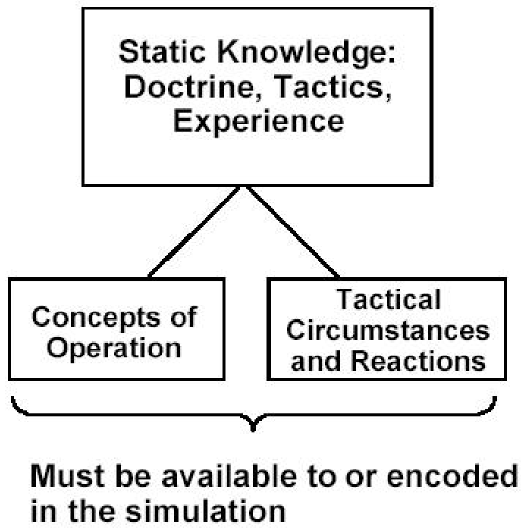


Figure 6. What is imparted with Static Display alone

The addition of dynamic information in Figure 7 illustrates the value of adding the dynamic aspect to a display. The current system is by and large a static display.

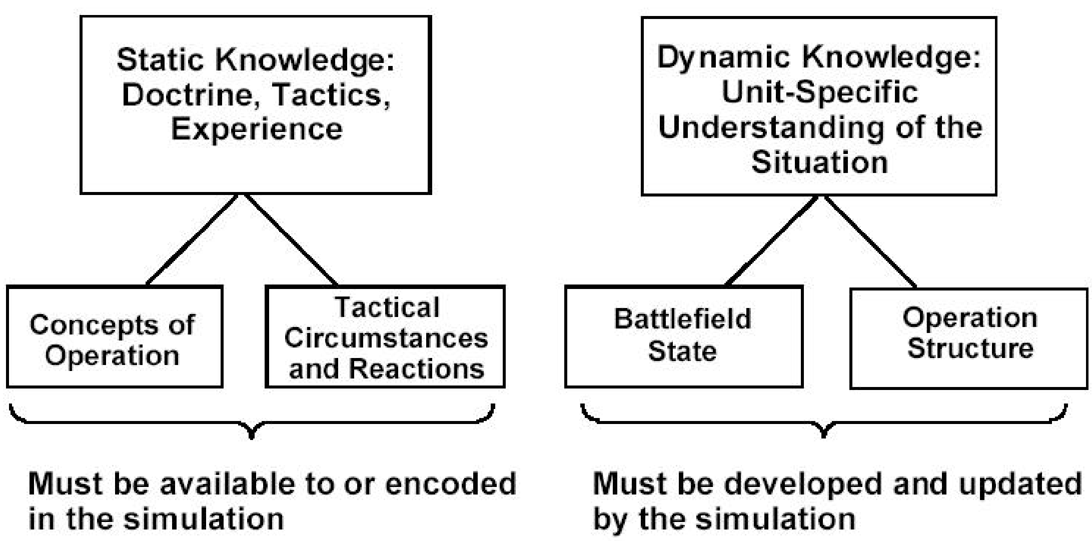


Figure 7. Information Gained by Adding a Dynamic Display

Information on the current system is inaccurate in terms of exact position, latent in terms of displaying any type of aircraft movement, and incomplete in terms of real time display of actual aircraft position and orientation.

We intend to make recommendations that will enable COMNAVAIRLANT and COMNAVAIRPAC to request NAVAIRSYSCOM to invest in developing an integrated solution for an updated Command and Control system. The “Fleet” requirements drive the development dollars. The cost benefit analysis of the current disjointed, inefficient system should make a strong case for a system that increases efficiency by allowing 100% data visibility and added decision support functionality.

This system will enhance the War Fighters ability to perform their duties by leveraging the technology that will make them more informed so that they may make more informed decisions. The need to improve Command and Control is well documented and is one of the priorities that any new system would strive to accomplish.

The need to model command decision support systems depends on increasing two items whenever possible; (1) Fidelity – to include cognitive as well as physical “battlefield” processes; and (2) Automation, in order to reduce the number of human decision makers in the loop[9].

In order for any system to accomplish an increase in value over the current, and very familiar, system, it must provide more than the status quo. To simply create a digital display that shows no more than the current system would be a wasted effort. Naval Air War Center, Lakehurst (NAWC Lakehurst) found

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[9] Donald K. Krecker: Martin Marietta Laboratories; John B. Gilmer, Jr.; Wilkes University; David C. Knox; Martin Marietta Laboratories; *Modeling Situational Awareness for Command Decision Making*

that the first digital version of any of the displays used aboard the Aircraft Carrier were nothing more than digital replacements. This has value in getting the users to accept the new version since it is visually the same. Feedback from users would only indicate the new system was a positive enhancement to the previous version when the new version expanded their capabilities. The Integrated Shipboard Information System (ISIS) is a prime example of this[10]. True value is added when the replacement system provides additional functionality that increases the user's abilities or situational awareness.

## C. SCOPE

The scope of this thesis is broken down into three primary sections. The first is to address the sensors that would be considered for use in capturing the raw data that the objects on the flight deck represent. There are many ways that such data may be brought into a computerized system; all of them have advantages and disadvantages in both the inherent properties of the sensor and in the way that they are employed. The carrier deck is a very extreme environment that is especially demanding on the equipment that is utilized in and around it. Many of the sensors considered could do a superb job if not for the fact that they will be subjected to jet aircraft exhaust, fuel spills, oil, hydraulic fluid, high winds, salt air, high humidity, etc. Additionally, the nature of the carrier and the equipment utilized there in requires the sensors to be low maintenance, accessible, and easily calibrated (either in place or aboard ship). All of these environmental factors will need to be mitigated in order for the sensor to be useful.

[10] From interviews of NAWC Lakehurst engineers

The second aspect is the display. We do not want to provide a solution that does not meet the needs or desires of the population we are attempting to assist. It is imperative that we conduct research into what it is the user wants this system to be able to do and what it will look like. Many of the "old salts" will resist the change outright. They may question the need to change a system that in their view "is not broken". In fact, it is conceivable that they would prefer to stick with what they know works. This familiarity with the existing system is natural and to be expected. Our coursework on managing change made this point abundantly clear. Again, sighting the ISIS work done by NAWC Lakehurst, it would behoove us to develop a system that is visually "similar" to existing systems.

The third aspect is the integration and processing of the sensor information and the other systems currently in place. This will also incorporate the ability for the system to predict "best" actions for given scenarios. Accordingly, the system may require multiple agents to facilitate the interactions between sensors and systems whenever a data call is made so that the user will benefit from accurate and timely information.

## D. ORGANIZATION

Understanding the aircraft carrier's operational organization from very general to very specific will impact the architecture of the system to manage aircraft handling on aircraft carriers. The organizational chart is an effective tool to help identify individual responsibilities and "need to know". More importantly, the charts initially help to delineate the "actors" or the individuals who either rely on the information summarized on the Ouija board to make decisions.

These are the individuals who have the power to add, change, or delete information that ultimately impacts effective mission planning and execution.

At a minimum, identifying those actors with “need to know” will help determine how the information on the Ouija board would be distributed. Because of the sheer number of potential actors, dedicated Ouija board repeaters will be cost prohibitive, but web enabling the display is a viable option. For example, if the Commanding Officer (CO) of a squadron wants to find out the status and location of one of his aircraft, the CO could log onto the closest computer, open a web browser, and enter the Ouija board Universal Resource Locator (URL) address. He could then query the site for information on the specific aircraft and have that information readily displayed.

The Ouija board is considered a key-supporting element in the command and control structure. The information represented on this element summarizes input from numerous sources and provide immediate feedback to all actors when changes are made.

The organization of the Aircraft Carrier, the Air Department, the Air Wing, and the Aircraft Squadron are depicted in Figures 8 – 11. Each block on the chart represents either a single actor (a Commanding Officer) or a group of individual actors (the Air Department). If some actors appear in more than one chart, this may be a function of granularity. For example, the ship has a Commanding Officer, but each squadron also has its own Commanding Officer.

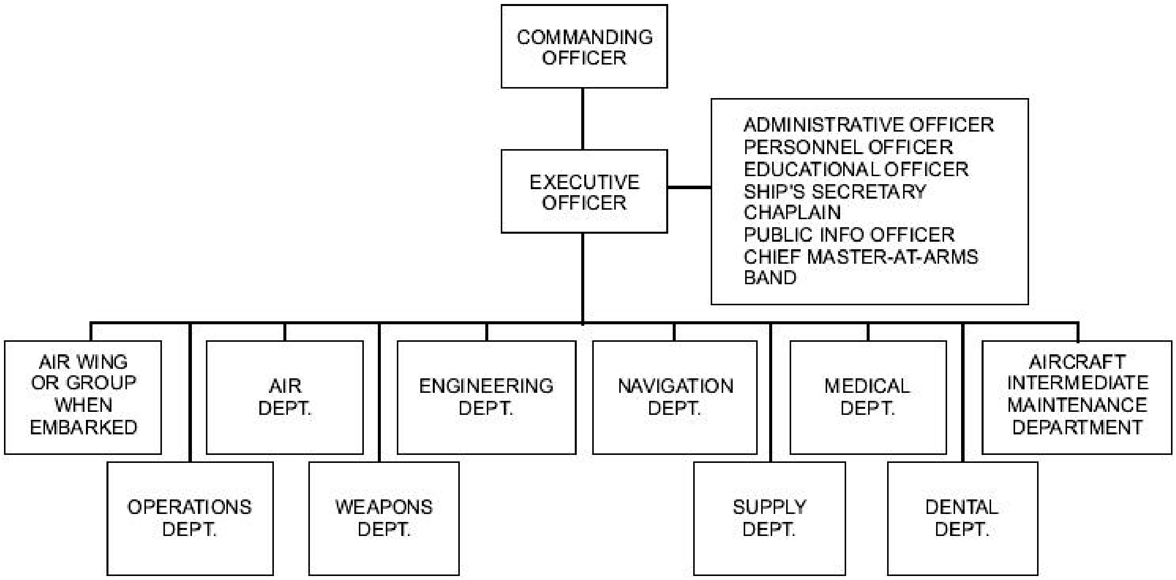


Figure 8. Aircraft Carrier Organizational Chart

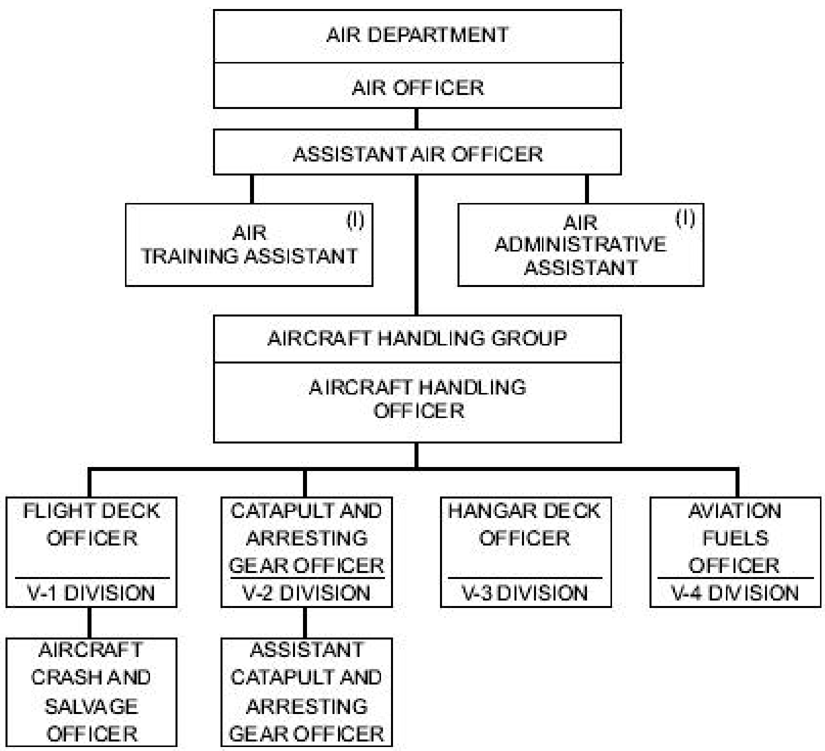


Figure 9. Air Department Organizational Chart

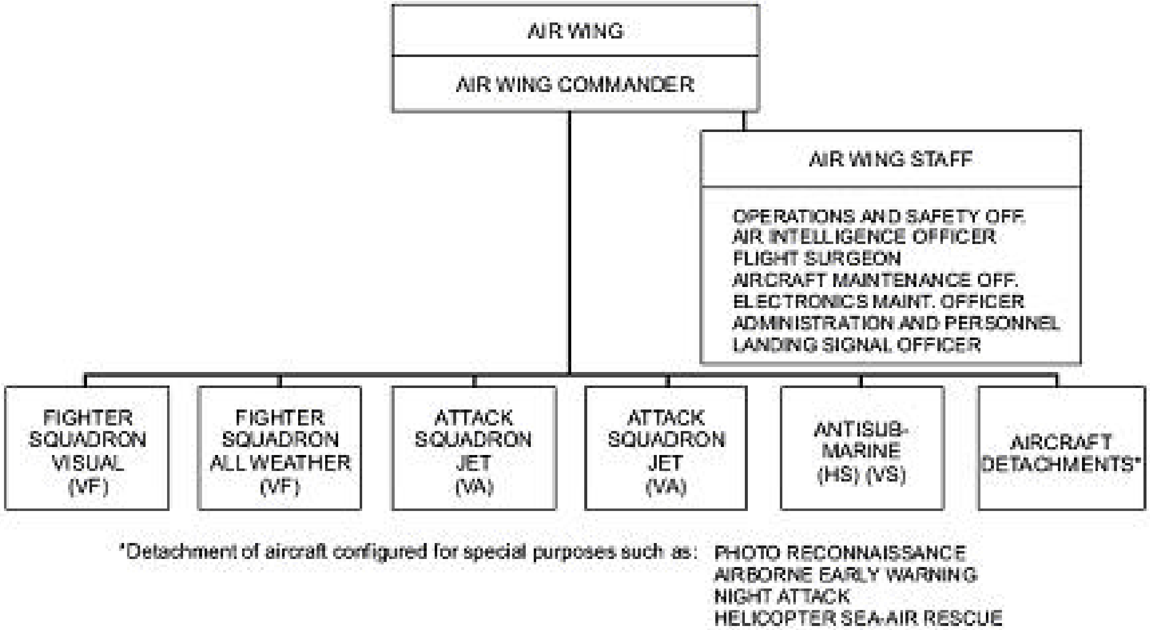


Figure 10. CV Air Wing Organizational Chart

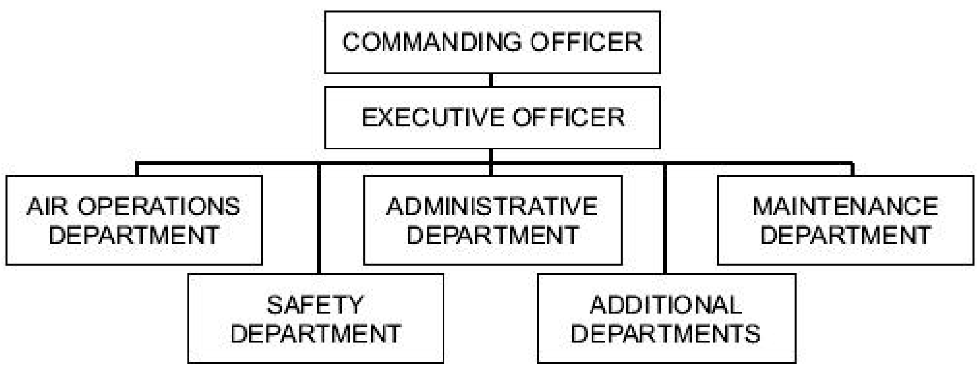


Figure 11. Aircraft Squadron Organizational Chart

From these charts, general responsibilities can be determined. For example, the Commanding Officer of the carrier will be responsible to maneuver the ship and provide many of the services to support flight operations. These services will include electricity, fuel, and even steam for the catapults. The status of these services may not be depicted on the Ouija board itself, but the elements should be captured on the master

database and considered in the broad execution of flight operations.

The Aviation Data Management and Control System or ADMACS is discussed and described in detail in Section III, Part D of this thesis. Appendix A provides specific actor input responsibility at the work center level for ADMACS. Many of these inputs will either be depicted on the Ouija board or will impact decision support elements being executed in support of the Ouija board.

# II. SENSOR EXPLORATION

In this chapter we will endeavor to describe several of the possible sensors that we considered as possible solutions to the data capture portion of our thesis. The list is representative, but not inclusive since there are certainly other sensors that we did not come across in our research. It does, however, provide a vast overview of the products that are available and to what degree they may apply to our problem.

Discussions with the engineers that have been working on numerous related projects and by the guidelines explained to us in developing the requirements in this paper, we need to consider the following with regard to Sensor Selection.

The sensors are required to involve no or minimal modification to aircraft for the following reasons: 1) Additional flyaway weight is frowned upon by the programs that are responsible for the aircraft. Keep in mind that weight is a critical factor in the performance and flight time duration. In the past, there has been much research into the type of paint to use in order to shave ounces off aircraft; 2) It may be bureaucratically difficult to require an across-the-board aircraft modification through nine different aircraft program offices; and 3) some identification tags are considered a Foreign Object Damage (FOD) hazard, something that could be ingested into a jet intake or fly up and hit someone on the deck.

A general consideration that must be addressed besides not being able to modify the aircraft is minimizing the aircraft carrier’s electronic emissions footprint. Laser ranging, although very precise in determining location and orientation of

aircraft, may have significant issues with scatter, stealth (especially with carriers operating in littoral regions), and eye safety. Major modifications to the ship would most likely be a showstopper.

Deck Sensors embedded throughout flight and hangar decks could “sense” aircraft; however, with one sensor per square foot, this approach would require extensive deck modifications. There would possibly be over 100,000 sensors on the flight deck alone. Wiring all of these sensors would be a major undertaking, especially since the majority of the space directly beneath the flight deck would be extremely difficult to access.

Conceivably, a vast network of these sensors working in a wireless environment could reduce the need for the data to be transmitted via cable, but then a reliable power source for the sensors and the transmitters would still be an issue. Even if this was a desirable thing to do, there are significant issues with mounting somewhat fragile sensors in an environment that is fraught with fuel and oil exposure, salt water intrusion, high winds and temperatures from jet exhaust, as well as the abuse of 70,000 pound aircraft, dropped chains and turning tires directly on top of the sensor. Additionally, these sensors are only able to sense pressure. For example, the system could detect the pressure of a wheel, but it would be difficult to integrate this information with other sensors or discern aircraft orientation from only one input. Further, the system could not easily relay information about the other wheels. This would also be the case for aircraft identification, configuration, fuel status and weapons load.

Differential GPS is accurate enough, but there are additional issues here beside the aforementioned “no

modifications to the aircraft" rule. GPS requires the sender to have a power source. The aircraft position information is needed when the aircraft is under its own power *and* when it is being towed or when it is parked. Hence, the use of GPS is also a non-starter. Again, if the aircraft modification and power needs were not an issue, there is the issue of requiring satellite information to determine the precise location of the aircraft on the flight deck. First, GPS requires simultaneous lock on a minimum of three satellites in distinctly separate sections of the sky. If only three where available, but two where close to the same line of site, or azimuth, then their information is no better than having only one satellite on that azimuth. Additionally, the GPS constellation consists of only twenty-four geo-synchronously *orbiting* satellites.

Geosynchronous orbits do not provide 100% global coverage – the Poles would be left uncovered, hence the system would not work when the carrier is deployed above the Artic or below the Antarctic Circles. Furthermore, GPS requires *line of site* from the sensor to the satellite. Even with the Hangar Deck elevator doors open, the majority of the aircraft in the hangar bay would not be in line of site with 3 GPS satellites at all times. Hence, another system would be required for the Hangar Deck. And, just like the other sensors mentioned thus far, the use of GPS would not afford the system orientation information, identification or configuration information.

We did consider the use of the aircraft's Identification Friend or Foe (IFF) signal for identification and location. This too is a non-starter for various reasons. First, it requires power and a user to input the correct codes that then identify the system to the ship's IFF receiver. Second, the aircraft IFF

is a power transmitter, and like aircraft radar, it is usually kept in a standby mode when on deck to avoid unnecessarily radiating the flight deck crew. It is likely that if all the aircraft where transmitting that the ship’s IFF interrogator would not be able to distinguish who is who. Since the IFF interrogation response is sent back via radio wave, it is transmitted via an aircraft antenna. The disadvantage here is that with all of the Air Wing aircraft on deck in very close proximity to one another, the antennas of many will be blocked from clear transmission.

Since the IFF was designed for use with the ship and aircraft radars, it is not optimized for use in pinpoint precision in a parking environment. Furthermore, the IFF position would be a point source, not a two-dimensional aircraft sized fix. As such, like the previously considered solutions, the IFF may be able to tell us where a particular aircraft is and which aircraft it is, but it won’t be able to determine orientation and configuration.

The Embarked Aircraft Tracking System’s (EATS, described in Chapter III) engineers considered other “visual” data inputs such as an Infrared (IR) camera. The benefit here would be increased ability in low light or foggy settings. The disadvantage would be the cost (high end IR cameras are upward of $100,000). Other detractors are that these cameras are less able to provide the resolution required to obtain precise position and side number identification information. Additionally, the aircraft image may be less clear when either the aircraft has cooled to the ambient temperature or when the environment is hot enough to blur the lines of distinction, such as when operating in the Persian Gulf.

We did a partial survey of varying types of sensors to get a better appreciation of what industry has to offer. The below sections are the details as well as our opinion of the pro's and con's of each system.

## A. IR OPTICAL TRACKING SYSTEM

The optical tracking system ARTtrack1 & DTrack software from *Advanced Realtime Tracking GmbH*, a German corporation, has been used for Virtual Reality and Augmented Reality. The system consists of tracking cameras ARTtrack1, passive targets and the PC software DTrack. Some of the advantages to this system are[11]:

- Position and orientation measurement with high accuracy
- Short latency, fast data communication via Ethernet
- Passive targets that do not require battery or wiring
- Tracking cameras with integrated IR flashes, complete software control makes them easy to use and easy to adapt to custom requirements
- Flexible system setup with fast calibration,
- Scalable system: no performance penalty for larger measurement volume covered with more cameras
- Robust against electric and magnetic interferences
- No optical cross talk between individual cameras

This system was developed for tracking for virtual reality and augmented reality, virtual TV studios, body tracking for animation and ergonomics, industrial measurement applications, and image guided surgery.

This system does not appear to be suitable to our application. One serious limitation to this system as it stands today is that it is limited to 10 targets. This may be less of

[11] http://www.ar-tracking.de/

a factor as the software matures, so it is worth mentioning here for future consideration. Another limitation is that this system does require markers on the targets (Figure 12), which is currently not permitted.

Figure 12. Marker Required for "ARTtrack1" Sensor System

Table 1 on the next page lists the technical specifications of the system. According to the company's data, the system seems to be extremely accurate with very little latency, attributes that are very desirable for our proposed system.

| | |
|---|---|
| data transfer | Ethernet 100 MBit/sec |
| frame rate | max. 60 Hz |
| latency | < 40 ms |
| max. number of targets | 10 |
| max. working distance | 4 – 10 m, depending on marker size |
| system calibration | within 5 min |
| body calibration | within 1 min |

**Accuracy of a typical ARTtrack1 & DTrack System (Example)**

| *Typical result for the tracking of a person's head position and orientation in a tracking area of 4m * 4m with a 4 camera tracking system.* | **target position** | **target orientation** |
|---|---|---|
| accuracy absolute (RMS over whole measurement volume) | 250 µm | 0.12 deg |
| repeatability (standard deviation) | 60 µm | 0.03 deg |
| maximum error (calculated) | 900 µm | 0.4 deg |
| noise (standard deviation) | 30 µm | 0.015 deg |

Table 1. ARTtrack1 Technical Data

## B. ELITEPLUS

The Italian company *Bioengineering Technology Systems* has developed a system that can track minute movements of people[12]. LITEplus is their new version of a fully automatic Motion Analyzer. The system features the ability to very quickly process and simultaneously collect analog and digital image signals. It is a real-time system; however, it is designed for and predominately used for biomedical purposes. It is not designed to track multiple targets, and therefore is not a true contender for use on the carrier, but there are some noteworthy characteristics that may apply to our application.

The system is designed to run on a general purpose PC, so no special hardware for the computing needs is required. The system is able to recognize minute movements and is extremely accurate.

## C. OPTOTRAK

The Canadian company Northern Digital Inc. manufactures OPTOTRAK[13]. OPTOTRAK is a powerful, highly accurate 3D motion and position measurement system. It is reported to be both flexible and reliable, attributes that make it worthy of consideration. According to Northern Digital, "OPTOTRAK is considered the premier choice of industries, universities and research institutions around the world. Incorporating specialized sensor technology and sophisticated optics design, the OPTOTRAK delivers superior performance in 3D tracking and measurement."

The system highlights some of the features that are considered positives in the industry. It is able to track

[12] http://www.bts.it/bts/products.htm, June 20, 2002

[13] http://www.ndigital.com/home.html, June 20, 2002

markers and rigid bodies, and it is able to identify markers automatically. When a track fall out it is reacquired and recognized immediately. Conversely, if the track reappears it is immediately associated and identified. These features may have direct application to the Digital Ouija Board since the likelihood of tracks dropping out of the system is inevitable.

Accuracy is an issue regardless of the technology used to acquire the data. Northern Digital claims that their system is capable of precise data collection that in turn delivers exceptional results. Conversations with their systems engineers revealed, however, that the accuracy when applied to the vast expanse of the carrier deck would be less than optimal. While the system is capable of RMS accuracy to 0.1mm and resolution to 0.01mm, the positional accuracy at the extremes of the flight deck could be as poor as 2 meters. It is our contention that this degree of accuracy, while better than the current eyeball method, is not accurate enough for the purposes of a truly automatic aircraft positioning system. The EATS prototype system is required to perform at no worse than eighteen-inch accuracy. This is the nearest we could find to a standard in terms of aircraft positioning accuracy on the flight deck.

Other favorable features of the OPTOTRAK system are the low setup and calibration properties. The system is calibrated in the factory so it is ready for immediate use once it is installed. No other user calibration is required thus eliminating daily downtime. The system can be pre-configured to collect and store data instantly.

Another potentially useful feature of this system is the “Multi-tracking” capabilities that allow simultaneously tracks of full body - hands and face with one simple system. Obviously

the design of such a feature did not have the application of tracking aircraft in mind, but this feature could be exploited for future applications that could conceivably monitor the catapult crews’ motions to ensure that no steps are missed or performed in the incorrect order while hooking up an aircraft. Other possible uses could be as a flight deck event recorder. When a mishap on the flight deck occurs, the replay of the deck activity could reveal hand signals that may have been contributory to the mishap. Or conversely, the system may be used to exonerate a crewman who was implicated of making a grievous error when in fact the system shows that his or her hand signals or actions where correct.

The system is capable of handling large, complex applications and can track up to 256 markers. The obvious issue here is that the system requires the aircraft to participate in the identification process, something that we have been prohibited from doing. Future versions may be able to use existing distinguishing organic characteristics of the aircraft, such as side numbers, as markers, and will be able to dispense with the current restriction that makes this and other systems unusable.

A detractor from this system is the lighting requirements. Although the system adjusts to suit most indoor environments and is not affected by normal fluorescent lighting or metallic objects, it was not specifically designed for use in the bright sunlight or in the near infrared environment. These are considerations that would need to be addressed to make the system useable in all lighting conditions.

There appears to be a few reasons why the OPTOTRAK System may not be the best solution for our project. OPTOTRAK is an

active marker based system requiring direct line of sight between the markers and the camera. The markers emit infrared light and therefore the system is designed for internal use only as sunlight will interfere with the marker tracking. The range in the depth dimension within which the OPTOTRAK can accurately determine 3 dimensional coordinates is 6 meters. The distance required is much greater than this to view aircraft on a flight deck. The Engineers at OPTOTRAK are quick to point out that the system has been engineered to obtain RMS accuracies to 0.1mm which is probably more accurate then the carrier based system requires.

Overall, there are some definite attributes to this system that have applicability to the Digital Ouija Board and could be considered as a technological contributor when the system is fielded.

## D. BOUJOU

Boujou is a camera tracker system developed by 2d3 Ltd, of Oxford, UK[14]. The system's main function is to recover camera motion from pre-recorded film or video footage. As a 3D camera tracking system Boujou takes moving footage from film or video and by analyzing the footage automatically it calculates the position and characteristics (yaw, pitch and roll) of the camera that had shot it at each frame or field. In calculating the camera motion Boujou will also calculate the 3D structure of the scene in the video sequence. This in turn could be used to generate the precise location of a target from the camera. The system starts the tracking process by finding hundreds of features it can identify in each image; it then builds up tracks

[14] http://www.2d3.com, June 20, 2002

of these features over time.  This feature could be useful in that the system would “learn” about the targets in its typical purview.

There are a few drawbacks that would disqualify this system from serious consideration.  Although it is a passive system, which is a plus, the system requires movement in 3D space in order to provide enough parallax information about the scene. If the camera is static then Boujou will not be able to work out how far away objects in the scene are (because there is no parallax).

This brings us to how we would employ this system.  Here the camera is static but some parts of the scene are moving. This situation may still work with Boujou, since the needed parallax would come from distinct objects moving in an otherwise static scene.  This has the added benefit of eliminating the redundant static scene since the system can be told to track the object and ignore the scene.  This could be useful in that the tracking will only be needed for moving targets.  Our system could simply create a last known fix for any target that stops moving, and the display will show that aircraft parked in its last known place and orientation.

The biggest detractor to Boujou is that even though it can carry out its tracking without the need for manual intervention, the calculations are NOT real-time.  This eliminates it as a viable alternative.  Additionally, the current technology employed in this system uses visible red or infra red light emitted from a ring of strobe LEDs mounted around the lens. Natural daylight will swamp the light reflected from the tracking markers, which would render the system useless on the flight deck.

## E. VICON 3-D OPTICAL MOVEMENT ANALYSIS SYSTEM

Vicon Systems[15], the sister company to 2d3, is located in Lake Forest, CA. They have done extensive work in object optical motion capture and analysis; optical human, animal and object tracking; biomechanics, animation, sports, medicine and engineering. Relative to this thesis is their Real-time Object Tracking applications. The 3-D optical movement analysis systems from Vicon can be used to track humans, animals, golf clubs, and other sports equipment. It has been used for precision instruments for surgery and other medical applications, as well as Head Mounted Displays, robots, shapes, cars, machinery, and others.

The Vicon system currently claims low latency, low noise and real-time data capability. They also claim to have a user-friendly communication protocol that allows users an easy interface to give them the ability to get trajectory, translation and rotational data into the system software.

Vicon's motion capture systems are comprised of three main parts: specialized cameras, custom-designed high-performance computer hardware, and interlocking software programs. Up to 24 high-definition Vicon cameras are arranged around the target area. These cameras are fitted with red or infrared strobe lights that illuminate small reflective markers fitted to the target whose motion data is to be captured.

The cameras feed the motion of these markers to the computer hardware in real-time and the software interprets the data to reconstruct the 3D shape and actions of the moving object. The system is extremely accurate.

[15] http://www.vicon.com/, June 20, 2002

It may not be practical to place 24 cameras around the carrier deck, nor is it conceivable that we would use infrared markers to highlight aircraft and other objects on the flight deck. It is noteworthy, however, that this Vicon system is able to integrate image information from so many different sources.

Since their system uses markers it cannot be used for our application, however the company is currently developing a system that will track without markers. It may be only a short while until they have perfected a system that may have application to the problem of tracking aircraft. Additionally, the engineer that we interviewed specifically mentioned that the new system would be able to track in ambient light. Their current system uses the Mega-Pixel Infrared Camera that allows users to obtain accurate 3-D positions of markers placed on all types of objects. Since they already have the ability to track using infrared, the low light level issue may be negligible, and with the addition of daylight capability, we feel that this new system is worth keeping in mind as the new the Digital Ouija Board is developed.

This makes Vicon a possible vendor who may be able to easily modify their existing and future systems to the Navy's needs.

## F. AUTOMATIC VIDEO TRACKING SYSTEMS

ISCAN Corporation of Burlington, MA manufactures the AVTS[16]. There description of the system is as follows:

> ISCAN Automatic Video Tracking Systems (AVTs) are real time digital image processors that automatically track the movement of contrasting targets within the field of view (FOV) of an electro-optic image sensor, such

[16] http://www.iscaninc.com/, June 20, 2002

as a video camera or a forward-looking infrared (FLIR) imager.

ISCAN AVTs provide digital and analog outputs corresponding to the position and size of contrasting targets with respect to the electro-optic scan lines of the imager. The position and size of contrasting targets may be easily interfaced to computer systems for data acquisition or linked to azimuth/elevation tracking mounts for acquisition and accurate tracking of targets over a wide field of view.

The ISCAN Model RK-447 Multiple Target Tracking System has the ability to track 256 simultaneous “targets” in real–time. ISCAN claims that their proprietary Simultaneous Multiple Area Recognition and Tracking (SMART) architecture is superior to other tracking systems that are easily confused by images containing more than one or rapidly changing target shape, which happens as the aspect changes in relation to the camera. The system is able to determine the targets' position and size data automatically. The system is capable of updated every 16 msec (62.5 frames per second) and the output is already designed for input to a computer. This refresh rate is significantly higher than that for motion pictures (30 frames per second) or the current EATS’s 30 frames per second. The frame rate may not be a real issue since the aircraft we are tracking are not moving very fast.

The ISCAN system is designed for simple operation and already has a fixed camera mode of operation, thus reducing the effort to make the system work in a reverse application where the system normally moves and is looking at stationary targets. This system will work either way. The ISCAN system can be used with many of the standard cameras commercially available today,

and can therefore take advantage of the camera’s low light capabilities, much like the EATS described in chapter 3.

ISCAN has designed the system to work on PC with standard software and hardware that is available off-the-shelf. This avoids the need for developing proprietary solutions that will eventually create maintenance and interface issues, as the system gets older.

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# III. CURRENT PROCESS ANALYSIS

## A. THE CURRENT SYSTEM

The current use and description of the system was outlined in the introduction. There are numerous projects that are in development or proof of concept that are worthy of discussion and description.

In preparation for this research, we developed an aircraft handler’s questionnaire for the operator on the flight deck. This questionnaire is in Appendix B. Appendix C features the modest feedback we received from the fleet. The primary benefit of including these two appendices in our thesis is to provide a baseline for future initiatives.

## B. EMBARKED AIRCRAFT TRACKING SYSTEM

This current prototype system is under development by NAWC Lakehurst and Develosoft Corporation in Boulder, CO[17]. The primary purpose of this system is to capture the aircraft position, orientation and trajectory then to display this information in a digitized form.

The contract was awarded to demonstrate the feasibility of an Embarked Aircraft Tracking System (EATS). EATS requires sensor imagery of the flight and hangar decks to locate, identify, and track carrier embarked aircraft. EATS will be fully automated and hopes to significantly reduce errors due to 100% field of view and sensitive imaging that can “see” in poor illumination and inclement weather.

[17] Navy Contract N68335-98-C-0137

Additional benefits that are available from the EATS are that any LAN connected air department space (e.g. Primary Flight Operations) has instantaneous access to embarked aircraft positions and status. Realize that the EATS sensor inputs provide far greater situational awareness of the decks than is currently possible with existing closed caption television (CCTV) or the Integrated Launch and Recovery Television System ILARTS[18] cameras. The system also provides more efficient data passing than the current communications system that relies on sound powered phones and hand delivery of information. EATS will have digitized video enhancement and will be able to provide capabilities that will allow digital illumination of dark areas. Specific users will have the capability to instantaneously zoom the view to areas of interest. The system will also have the capability to digitally record flight operations or deck activity so it can be replayed (in fast forward, reverse, single frame modes) and be used for training, planning, and optimizing sortie rates.

As mentioned previously, EATS is a developmental application to prove the concept of 100% visualization of the flight deck and digital display of what the system “sees”. From

[18] In order to constantly monitor flight operations, aircraft carriers employ a system of cameras and displays called the Integrated Launch and Recovery Television System. The ILARTS system allows the ready rooms, flight deck control, and the combat information center to view recoveries, launches, aircraft movements on the deck, and other activities, enabling a rapid response in case of emergencies as well as a tape archive that can be used to investigate a mishap. A key component of ILARTS is the manned island camera, which is located about 40 feet above the flight deck. The island camera is a pan, tilt, and zoom (10:1 zoom lens) that picks up the aircraft as it grabs one of the arresting wires, zooms in for a close up to pick up the aircraft’s side number and follows the arresting wire back to its sheaves to determine which of the wires was engaged. If the aircraft bolters, the cameraman follows the aircraft as it departs the ship. The island camera also tracks each of the aircraft as it launches from the time it is in the catapult out to a half-mile.

our perspective it is a data input system that seems to be working well[19].

> The goal of establishing the feasibility of embarked aircraft tracking from carrier-mounted sensors has been achieved. Many hours of test imagery were acquired during day and night flight operations aboard the USN Carl Vinson (CVN 70). This imagery was successfully used to demonstrate accurate identification and location of aircraft with advanced image processing, pattern recognition, location, and tracking. These algorithms were tested under numerous difficult conditions: obscured aircraft; nighttime; severe optical distortion and optical aberrations (blooming); and camera motion. The test and demonstration environment consists of a split screen Windows application with recorded video images appearing with digitized stationary and moving aircraft (whose type and positions were computed through EATS algorithms). The accuracy and speed of EATS algorithms is easily demonstrated within this environment on numerous video sequences (day, night, flight and hangar decks). It is readily apparent that computed aircraft types, wing articulation, positions, and orientation are correct.

The research and development of EATS has in effect proved the concept of a sensor driven system that can input data to a system, and then display that data as real-time tracks on a digital display.

It is our opinion that this system is very capable of performing its stated function. From the limited amount of feedback we received from NAWC Lakehurst, the system does not provide the Handler with as much information as he has currently. If the EATS were fielded today, it would not be able to replace the Ouija Board as the Handler’s primary decision support tool. EATS is a significant improvement in that the

[19] Based on E-mailed information from Develosoft

Handler, in our opinion, should have - a significantly better picture of where all the Air Wing aircraft are at any given time.

It has been reported that the EATS system does not have the capability, at least in its current form, to assign side numbers and to apply the pins, nuts and washers (again, this is referred to as “nutology”). This limitation makes it less useful than if it were able to do so, but as stated earlier, it still shows an accurate depiction of where the aircraft actually are on deck.

This is an important and successful evolutionary step of bringing the Ouija Board into the digital age.

EATS also confirmed our theory that CCD cameras are good sensors to use to establish the four orientation parameters (X and Y coordinates, orientation and trajectory). Cameras have the advantage of being non-invasive (that is to say nothing need be done to the aircraft being “sensed”). This is imperative because coordinating concurrence by each of the different program managers for each of the different aircraft (F-14, S-3, C-2, etc.) would be very difficult. If a sensor or appliqué such as a bar code label or other identification tag were to be used, each individual aircraft Program Manager or PMA would have to be involved and would have to agree to the design or application. The engineers at Lakehurst assure us that the aircraft PMA’s have been known to split hairs over the type of paint used on their aircraft. It would be exceedingly difficult to get a consensus if such a single sensor or label could even be identified.

As mentioned in Chapter II, another consideration for aircraft mounted sensors is the power source. Some sensors, such as the IFF (Identify Friend or Foe) or Differential GPS

would only be useful when the aircraft was running on its own power (or on the Auxiliary Power Unit (APU)) or when connected to ship's power (and the sensor system is turned on). There are even other considerations for emitting type sensors. These systems are "telling" the receiver on the ship where they are. An adversary able to electronically eavesdrop could exploit these emissions for his own purposes including targeting. An imposed Emissions Control (EMCON) condition would be another consideration. Depending on the level, all active electronic transmissions from the ship would have to cease.

These same limitations would apply to a radio based system, such as the IFF currently found on all military aircraft. Here too, there are even more show stopping considerations. Differential GPS and IFF based systems would require more than one transceiver to accurately ascertain the target's relative position and orientation. If one of these transceivers was obscured or otherwise inoperative, the complete picture of the aircraft orientation might be lost. Furthermore, these active devices cannot relay configuration information, such as wing position, without some sort of additional equipment or methods.

The EATS developers are also working on a camera system that would replace the ILARTS. We were able to observe some of the work on this system as well. The first impression was that the system uses a relative limited design that uses a pan-tilt CCD camera, similar to the cameras used on many U.S. highways.

In our opinion the pan–tilt–zoom camera may be an excellent way to acquire the identification (which in turn provides the aircraft type) for the system. However, the trade off would appear to be a loss of visibility on the rest of the 4½ acres of flight deck as soon as the camera moved.

Our observations of EATS lead us to believe that it is advantageous to incorporate two design criteria into the Digital Ouija Board. The first is the use of more cameras. The second is to use a human to initially identify objects or aircraft for the system. The use of more cameras allows for complete coverage of the flight deck at all times. This ubiquitous coverage is required for the system to "know" where all the items of interest are at any given moment.

The ILARTS system provides important information for safety and other considerations. The use of the pan–tilt–zoom camera for this application would appear to be appropriate since it specifically is looking at one aircraft at a time. It is conceivable that an EATS type of system could be used in lieu of the ILARTS system, but this is beyond the scope of this paper.

The second design parameter highlights what we consider the advantage of the use of computers to enhance the human's abilities. Computers are exceptionally good of keeping track of the varied items in the cameras field of view. They can crunch the mathematical location information for the display based on the input from the sensors. Computers have a much more difficult time identifying objects, especially when the objects are at varied distances and orientations to the camera, and particularly when many of the objects are visually similar (from many aspects, the F/A-18 looks very much like an F-14) or when identical objects only vary by few distinguishing characteristics (such as the side number). We question the need for having the computer identify specific types or side numbered aircraft. Given that this system is being developed to enhance the human's ability to perform his or her job, it makes sense to have the computer track the objects but initially have the human

identify them. The current system uses human operators to provide this exact information. The introduction of a system such as the one we are proposing is not intended to replace personnel, but to increase their efficiency and aid them in decision making.

The system should be able to know where a particular object or “target” is wherever it moves on the flight deck. Once the target is identified, the system will then continually associate the identification of the target with its location track. This is analogous to the aircraft tracking system used by the FAA or CATCC. The system does not need to expend energy (and computing resources) revalidating the identification of the track once that identification is acquired. Should the system lose visibility or disassociate a track from its identification, the system could request the operator to revalidate, or re-identify the track.

One possible method of how this could be done is to provide the “raw video” (the image the camera is actually recording) to the operator in a “screen in a screen” scenario, much like that found in many new TV sets. By simply popping up a raw video image of an aircraft, the user / operator is prompted to quickly re-identify the aircraft to the system. Once the track has the required identification, the raw video image window would close.

The known processes of handling aircraft, as depicted in Figures 13 and 14, could be broken down into elements and used by the system to anticipate aircraft movement and notify the operator when actual activity deviated from what was (programmed) to be expected.

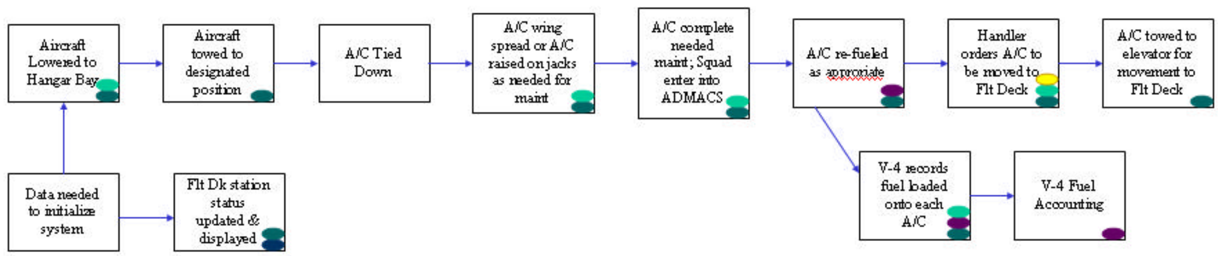


Figure 13. Hangar Deck Operations Flow

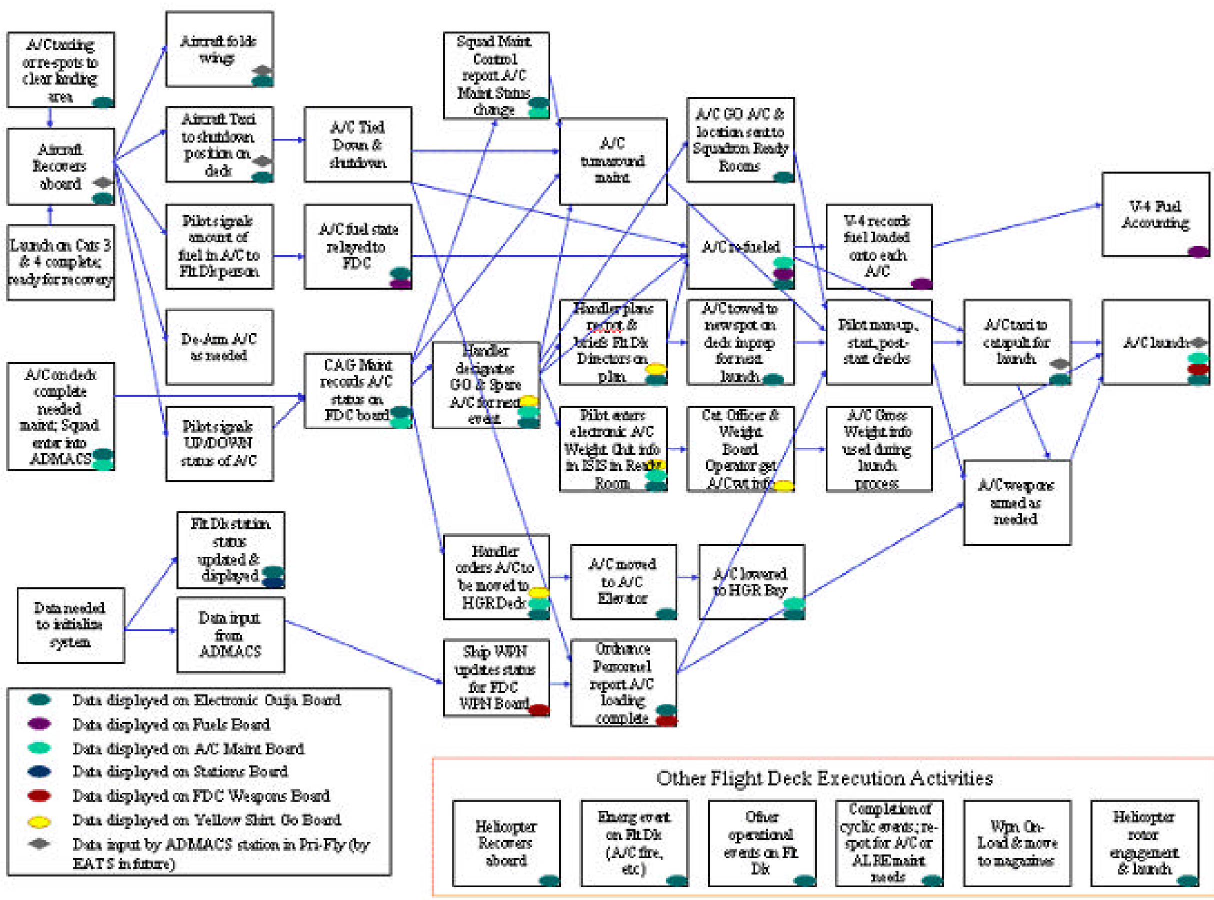


Figure 14. Flight Deck Flow of Operations

The Digital Ouija Board multi-camera system would have the ability, just as the current EATS system, to track and record data from each camera. The data can be in the form of positional coordinates or, as mentioned above, as a composite

video display. But more importantly, the system would not only statically provide current object location and orientation, but also dynamically "remember" past object movement and compare this movement to the process model to anticipate possible conflicts.

For example, if two aircraft needed fueling and were moving towards the same refueling station, the system could prompt the operator to direct the second aircraft to the next available station for simultaneous fueling as opposed to having the second aircraft wait.

## C. AVIATION DATA MANAGEMENT AND CONTROL SYSTEM

Aviation Data Management and Control System or ADMACS is a first attempt to create a universal database for the use of all the flight support applications currently aboard US Navy ships. The following describes some of the functionality that is required for ADMACS[20]:

> (ADMACS) will provide the Aircraft Launch and Recovery Equipment (ALRE) and air and flight operations (Air Ops) supporting work centers on aircraft carriers (CV/CVN class ships) and amphibious assault ships (LHA/LHD class ships) with a real time, fault tolerant (redundant), configuration managed, tactical Local Area Network (LAN) with an open system architecture in response to the emerging requirements to manage the data flow within and among these work centers and be the data source for information to be exchanged with other Command, Control, Communication, Computer and Intelligence (C4I) systems. An Evolutionary Acquisition (EA) approach will be used to facilitate fielding state-of-the-art systems capabilities keeping pace with evolving ALRE and Air Ops requirements. Within the ADMACS program, a number of acquisition

20 Operational Requirements Document For Aviation Data Management And Control System(ADMACS)

> phases will be in progress simultaneously. The ADMACS development and implementation will be divided into five increments. Each increment will be managed, funded, developed and tested separately and will comprise system(s) which contribute to the overall ADMACS development objectives and address the specific requirements of that particular user community.

Surprisingly, the last sentence mentions how the different phases will be managed and funded, but nothing is mentioned on how the various phases will themselves be integrated. Neither is it articulated on how the Program Manager intends to get all of the adjoining systems to either conform to the data structure that the ADMACS is using or how ADMACS will eventually eliminate the need for all the other systems to acquire and store their own copy of the data.

The ADMACS network is complete with redundant workstations for input should the primaries go down, UPS for continued power in the event of a power outage, and a thorough plan for the users to follow in the event of system problems. In order to better understand the data flow through the ADMACS system from the user perspective, an Input/Output Survey was made. Appendix D features this survey. The modest survey responses are in Appendix E.

The network diagram in Figure 15 shows the complexity of the ADMACS network and all of the workstations and different departments that it integrates to[21].

[21] Figure 15 is actually incomplete, for more of the network topology, reference the NAVAIR 51-15ABH-1-74 Operation and Maintenance Aviation Data Management and Control System (ADMACS) And Integrated Shipboard Information System (ISIS), section 003, pages 11 thru 17).

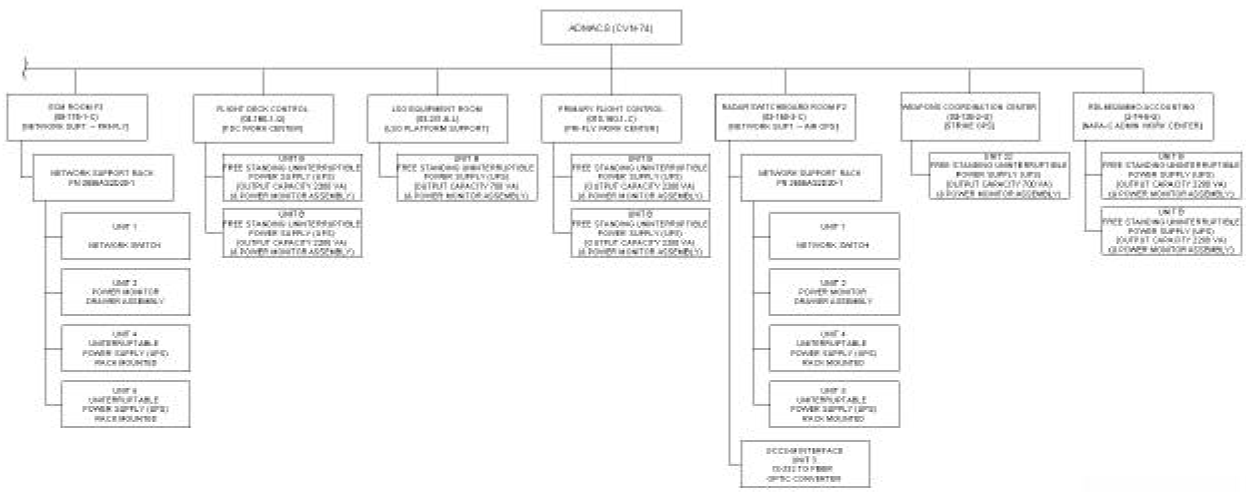

Figure 15. Portion of the ADMACS Topology

Our concern with ADMACS has less to do with the concept than with the actual implementation to date. We agree wholeheartedly that their needs to be a system that allows all of the various users in distinct locations, most remote to each other, to have complete data visibility. We have not found satisfactory reasons as to why the system has been so long in development and why, after nearly ten years, many of the needed features are still not included. The proposed Block II upgrade will, if developed as depicted, bring a great many more shops on line with the ability to interact. This is needed to provide data that others will need for their Plan-Decide-ACT (PDA) cycle. But as it stands, the only hard coding behind the Block II Upgrade is a 40 slide Power Point presentation that the engineers have pieced together in order to make the appropriate sales pitch to eventual users.

The need for a total system has been established, unfortunately, there does not seem to be a clear set of requirements, provided by the OPNAV sponsor, for the engineers to write code and develop the tool. Further, the current

version of the tool is not widely deployed. A full deployment of the tool to all operational units would generate the feedback to improve the system with Block Upgrades, vice bring in additional capabilities that could have been included in the initial release. It appears that the developmental prototype was released for general use, a less than desirable scenario for software development.

Additionally, the use of specific (out dated) hardware tightly coupled to the system will make it very difficult to expand the capabilities of the existing software. It also makes it difficult to implement the system on the ships that do not have the system yet or provide repair parts for installed systems because the original hardware is no longer manufactured. The Hewlett-Packard computer, currently used, has been out of production for several years. In the meantime, the systems command is apparently stockpiling available parts and retrieving older systems from Defense Reutilization and Marketing Office (DRMO) sites around the country.

## D. INTEGRATED SHIPBOARD INFORMATION SYSTEM

The Integrated Shipboard Information System (ISIS) replaces the Plexiglas status boards used in Air Operations (AIR OPS), Carrier Controlled Approach (CCA), Primary Flight Control (PRI FLY), and Flight Deck Control (FDC) with monitors and large screen displays. Officially, the ISIS is an integrated part of the ADMACS in that it uses the information from the other shipboard systems to acquire the information that it displays[22].

ISIS is an electronic data processing and display

[22] NAVAIR 51-15ABH-1-74 Operation And Maintenance Aviation Data Management And Control System (ADMACS) And Integrated Shipboard Information System (ISIS), section 003, page 3

system facilitating the timeliness and accuracy of air operations information provided to decision makers onboard CV/CVN class ships during shipboard flight operations. ISIS interfaces with other shipboard tactical, navigational and meteorological databases. Through ADMACS, ISIS enables rapid input; collection, processing and distribution of air operations data and the display of this information to all required ALRE and Air Ops work centers throughout the ship.

As with ADMACS, most of the Fleet Carriers and Amphibious Assault Ships do not have the system yet. Our best information indicates that NAVAIR has spent over $74 Million on the development of the ADMACS and ISIS systems. The schedule for the deployment to the remaining ships is detailed in Appendix F.

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# IV. PEER-TO-PEER (P2P) NETWORK COMMUNICATIONS

## A. INTRODUCTION

It is important to emphasize that the Yellow Shirt on flight deck is the Aircraft Carrier’s best and most reliable sensor. What steps must be taken to connect the Yellow Shirt to the system that manages aircraft movement?

It seems logical to push digital information to the sailors on the flight deck to increase operational environmental awareness. More importantly, if the system can request specific information from people in the environment, the accuracy of the operational picture depicted on the Ouija board will be that much better.

Communication on the flight deck is primarily visual, but radios are also used. Emergent technology including hand-held devices and wearable computers could be used. As discussed in the introduction of this thesis, the more visual information provided to deck personnel, the better for the system.

Ideally, the flight deck should be viewed and managed as a network. If each aircraft and each person is treated at a node on that network, the issues of facilitating communication and flow of information becomes a pure network management exercise. Primary network management issues that could be addressed in this context would be Bandwidth Management, Scalability and Mobility, Reliability, Communication Integration and Self-Organizing Behavior.

Naval Postgraduate School, in association with the Joint Futures Laboratory, Joint Forces Command and the Joint Experimentation Directorate, conducted a Limited Objective

Experiment (LOE) to examine Peer-to-Peer (P2P) computing on hand-held and portable devices in a wireless network environment. The primary objectives of the experiment were to demonstrate the potential of wireless portable P2P computing technologies and explore how the technologies could impact operational Command and Control. Many of the findings generated as a result of the LOE can be directly applied to the flight deck communications solution.

While it was outside the scope of this thesis to execute a limited objective experiment on flight deck communications, the P2P LOE findings did demonstrate that elements of network management should be taken into consideration when designing a comprehensive aircraft handling system. The system could be designed with future functionality in mind. Limiting system functionality to available hardware and software is shortsighted, considering technological advances.

Peer-to-peer computing is the sharing of computer resources and services by direct exchange between systems. In a peer-to-peer architecture, computers that have traditionally been used solely as clients communicate among themselves and can act as both client and a server, assuming whatever role is most efficient for the network. This concept of computing isn't new (the idea is over thirty years old), but the emergence of faster computing power, larger bandwidth capability, and relatively inexpensive storage, warrants serious reconsideration.

A recent example of successful P2P computing would be the universal file-sharing model or exchange of digital music files via the Internet popularized by "Napster".

The P2P LOE at NPS used an urban hostage scenario and Reconnaissance and Surveillance Teams (RST's). The RSTs used

hand-held and portable wireless-enabled devices to build environmental and situational awareness. This awareness was used to augment the planning of a subsequent hostage rescue mission.

## B. NOC ROLE, P2P WIRELESS NETWORK BUILDING BLOCKS

The main role of a Network Operating Center (NOC) is to manage and maintain network hardware and software. During the LOE, the NOC provided a high level of situational awareness that was fed to both the NPS Command Center and J-9 Headquarters. This awareness assisted the LOE team members to maintain consistent communications during the experiment, and to collect the experimental data. On the flight deck, the ability to maintain consistent communications is crucial. It is not unreasonable to envision an expanded role of the Flight Deck Control Center to include this type of network management.

The research role of the LOE NOC was to explore the feasibility of bandwidth management for P2P collaborative application clients, scalability and mobility of collaborative network, integration of P2P with client-server communications, and feasibility of P2P collaborative network self-organizing behavior. The LOE NOC accomplished these research tasks by implementing various means of network configuration, performance, and fault management to observe network and applications behavior.

The first step in managing the network involves developing a network model. The NOC manager begins the modeling process by creating or capturing the network topology.

## C. SIMULATION, ANALYSIS AND RESOURCE ALLOCATION

Once network topology is completed, a software simulation tool can be used to predict expected network performance. The simulation enables decision makers to predict efficiency and capacity of a proposed network before equipment is actually acquired. Simulation results also provide detailed information on network traffic and can differentiate, for example, the traffic attributable to the wireless segment of the network. Other useful performance elements include LAN load, throughput, data dropped, delay, media access delay, HTTP traffic sent, HTTP traffic received, HTTP page response time, and HTTP object response time. This data becomes crucial when allocating actual resources. The same date can be used to anticipate limitations that would impact operational success due to system reliability.

## D. MODELING, FLOW CAPTURE AND APPLICATION ANALYSIS

Commercial products such as OPNET's Application Characterization Environment (ACE) Application can be used to capture packet data necessary to analyze application specific loads. Files and associated packet traffic is traced and documented to create an accurate model of network data exchanges. This data can be used to populate both the application layer and network layer views in OPNET.

ACE can also be used to analyze the use of IP addresses. Dynamic Host Configuration Protocol (DHCP) provides a means to dynamically allocate IP addresses to computers on a local area network (LAN). The system administrator assigns a range of IP addresses to DHCP and each client computer on the LAN has its TCP/IP software configured to request an IP address from the

DHCP server. The request and grant process uses a lease concept with a controllable time period.

In the case of flight deck operations, permanent IP addresses would be more appropriate than DHCP since there are a finite number of possible nodes on the ship (aircraft, support gear, sensor and people).

## E. NETWORK MANAGEMENT SOFTWARE AND SNMP

Products such as Spectrum Network Management Software enable NOC managers to "drill down" into the network and provide detailed views of the network at user-defined levels. Alarms or customized notifications can be established. System status changes can be indicated by a change in the associated component icon color (from red to yellow depending on the parameter). Various views of the network can also be customized including:

- "Cablewalk" view: The layouts of the access points that are connected to the LAN. Detailed information about each access point can be viewed by double clicking the associated icon.
- Device Topology. This detailed view displays each network component. A normal connection is represented by a green color. An icon will turn red if performance has fallen beneath a set parameter. A yellow icon will represent the component nearing the parameter.
- Link State View. Each component will display a green, yellow or red color depicting the health of the link.

Simple Network Management Protocol (SNMP) is the Internet standard protocol developed to manage nodes on an IP network. SNMP is not limited to TCP/IP. It can be used to manage and

monitor various types of equipment including computers, routers, and hubs. It is used extensively by Spectrum to discover, model and monitor a network. Active TCP connections can be monitored for any SNMP compliant asset on the network.

## F. NETWORK PERFORMANCE AND FAULT MONITORING

Network management software can facilitate effective event tracking and system monitoring. The tools are versatile and can allow participants to see how activities might impact the health of the network. There are sufficient user-defined parameters and alarms that allow the NOC to shift assets to avoid hindering packet traffic during an operational scenario. Solarwinds Network Management System is commercially available software that can be used to monitor elements of network performance and faults. These elements include Network Performance, Current Response Time and Percent Packet Loss, Average Response Time and Percent Packet Loss. Information can be displayed graphically or in a tabular chart.

Network performance and fault management can be monitored simultaneously. Elements of fault management that can be evaluated include:

- Events and traps originating from wireless network elements.
- Configured alarm parameter levels. Source, severity, and type are documented.
- User-defined action scripts registered for certain alarm types or network element instances. Actions could initiate NOC manager notification through e-mail or pages (beeper).

- Color-coded hierarchy display for alarm level indications. Examples included minor (yellow), warning (cyan), major (orange), critical (red), informational (white), and decommissioned (blue).
- Reported number and time distribution of selected alarms, alarm severity, alarm state, or network elements affected.

NOC managers can determine alarm configuration and use the alarms to indicate network trouble before problems are actually realized. For example, if a network has severe packet loss between nodes, this would be clearly indicated and documented in the network, management software logs. Major alarms would appear if a node lost total connectivity from the network.

## G. BANDWIDTH MONITORING

The bandwidth monitor feature of Network Management Tools provides a variety of display options. Information can be displayed either graphically or in a tabular chart format.

The primary limitation of this function is that each network asset has to be SNMP compliant (Simple Network Management Protocol was discussed previously in section E of this chapter). In the example of the P2P LOE, only four of the six (laptop) terminals had functional Management Information Bases (MIBs), so Bandwidth capability could only be monitored on the servers.

A MIB is a database of managed objects accessed by network management protocols. An SNMP MIB is a set of parameters which an SNMP management station can query or set in the SNMP agent of a network device (e.g. router).

The SolarWinds TraceRoute module can also be useful in evaluating bandwidth usage. The utility will not only document the packet traffic paths taken from each node on the network, it also displays selected SNMP information about each device encountered. TraceRoute can be used to evaluate or query SNMP compliant machines outside the network. Packet response time and packet loss information can also be displayed both as a number and as a bar graph.

### H. P2P LOE FINDINGS

Factors affecting overall performance of the LOE network appeared to focus on the application layer of the OSI model. Performance metrics were not consistent across all devices, but this could be attributed to location of the individual teams relative to the wireless access points or individual laptop application configurations with regards to processes running in the background on each node.

The primary recommendation to improve application packet transfer would be coordinated turnkey configurations on each node of the network. Specifically, adjust the system configurations so there are minimal applications running in the background on the nodes.

A mobile node should be able to monitor its own signal strength and bandwidth utilization. This was a critical form of operational feedback provided to the teams from the NOC. The result was the teams adjusted their physical location or changed applications being used on their devices.

The experiment demonstrated the scalability of a wireless P2P collaborative networking, yet emphasized the network overhead needed to synchronizing voice over IP communication.

Voice packets were sequentially routed with other application packets, but the result was seemingly broken communication. Other traditional voice communication modes were more reliable. The data sharing features scaled-up effectively.

The experiment demonstrated that P2P and Client-Server integration is feasible, but sensitive to roaming between the access point coverage areas.

Application sharing was especially sensitive to roaming, as applications would drop when a team crossed a boundary of access point coverage. There was substantial packet loss until the application was restarted in the new area, so error checking and system synchronization/restoration features are necessary.

Self-organizing behavior was demonstrated when Reconnaissance and Survey team members switched modes of communication due to signal loss or interference. Yet, the strongest (and unexpected) effect of self-organizing behavior emerged at the command and control center site when network center managers were able to effectively monitor performance and fault data, synchronize this data with the voice and data sharing calls, and adjust assets or operations before packets and connectivity between peers was lost. Essentially, new channels of communication between team members were facilitated in real time by the NOC monitoring team elements.

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# V. MACHINE VISION

## A. INTRODUCTION

The biggest challenge in developing the conceptual design of the next generation Ouija board is formulating how action in a dynamic operational environment could be captured, processed, interpreted, summarized, and displayed for decision makers in “real time” or as action occurs.

The technology is available to digitize the display of the Ouija Board, but simply replacing the physical templates and representative hardware with virtual icons will not be value added. The optimal solution would have to automate the capture and display of object location, orientation, and movement. This solution could share the summary operational picture and associated information with all the actors and stakeholders who contribute, interact, use or service aircraft in their jobs on the carrier. Further, the solution would have to help collect, collate, correlate, interpret, analyze, summarize and display all input from the systems that impact flight operations.

The present Ouija Board is located in Flight Deck Control (FDC). A decision maker can either call FDC and ask questions about the operational picture or physically visit FDC to see the static board. The optimal system would web-enable the summary display so the operational picture could be easily seen from a browser on any computer with access to the ship’s network.

A caveat to this project was that, when considering possible solutions, no hardware could be added to any aircraft. So we logically considered different sensors and methods for capturing the required information passively. As discussed in

Chapter 2 of this thesis, there are several commercial systems available for capturing object information.

## B. PASSIVE VISUALS SENSORS

Aircraft location and movement information are currently captured and reported in the process described in the introduction of this paper. Human beings capture information. Therefore, for the purposes of this chapter, the proposed sensor component of the next generation Ouija Board will be compared to the human sensors currently used.

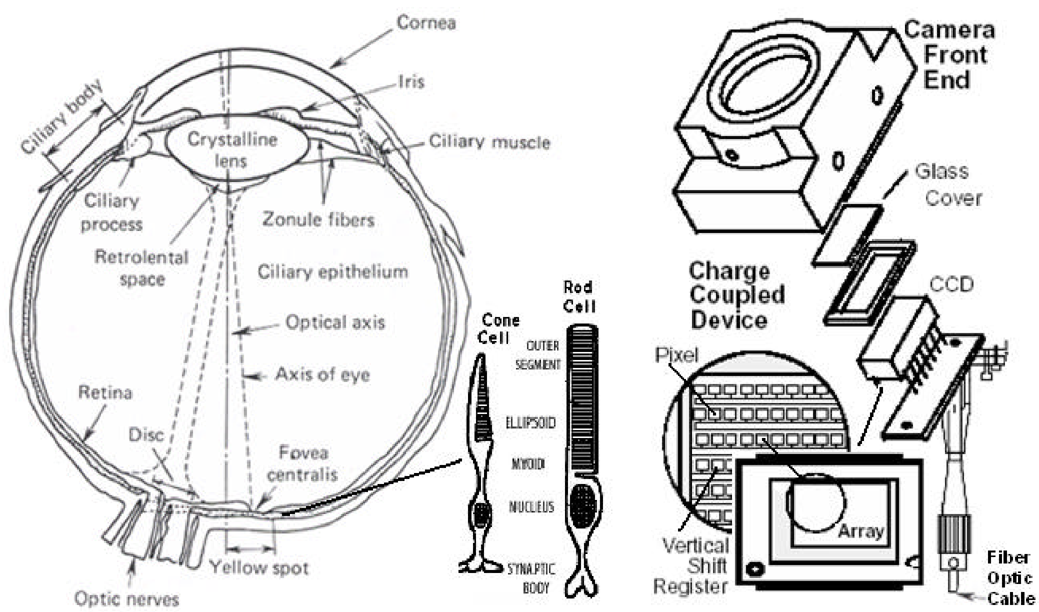


Figure 16. The Human Eye[23] and the CCD Camera[24]

The primary human sensor for capturing and reporting aircraft location, orientation, and status is primarily the human eye. As shown in Figure 16, the human eye and the

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[23] Three-Dimensional Imaging Techniques, Takanori Okoshi, "Construction of the human eye"

[24] The CCD Camera portion of this illustration is from http://www.pulnix.com/imaging/pdfs/primer.pdf, PULNiX America, Inc., Industrial Products Division, "Introduction to "Video 101""

standard Charge Coupled Device (CCD) or digital cameras have similar characteristics. The cornea protects the human eye while a glass cover protects the CCD. Each has a lens and an area to receive and interpret the ambient light reflecting off objects in the environment. The human retina has rod and cone cells that capture and encodes image data while the CCD has an array of pixels and either a horizontal or vertical shift register. The eye's data is transmitted forward via the optic nerve where the CCD transmits its data via fiber optic cable.

## C. LANDMARKS AND SENSOR LOCATION

Where could passive sensors be located in the operational flight deck or hangar bay environment? During the data collection visit to USS TRUMAN (CVN 75), the authors noted the symmetrical location of all the aircraft securing points (padeyes) on the flight deck as illustrated in Figure 17.

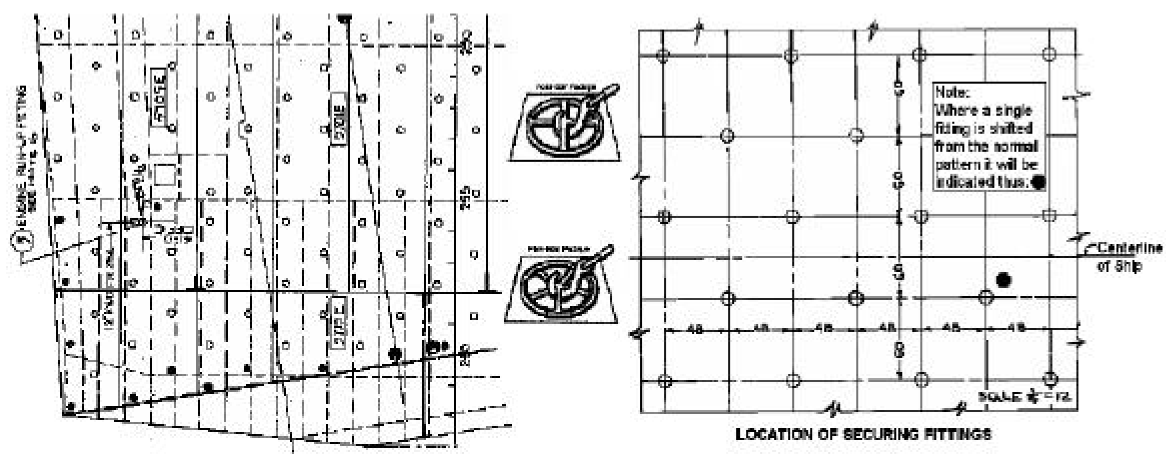


Figure 17. Aircraft Securing Points (Padeyes)[25]

As discussed in Chapter II, visual or pressure sensitive sensors could be installed in each of the padeyes on deck, but

[25] This illustration was compiled from actual ship's drawings for the Nimitz class Aircraft Carrier.

the initial installation, associated wiring, and subsequent required maintenance would be cost-prohibitive. Also, these sensors would only be able to look up at the bottom of an object or sense pressure when an object was actually upon it.

The primary benefit of noting the symmetry of the padeyes in the flight and hangar deck is that the padeyes can be used as landmarks or reference points to assist in localizing where an object is on the deck.

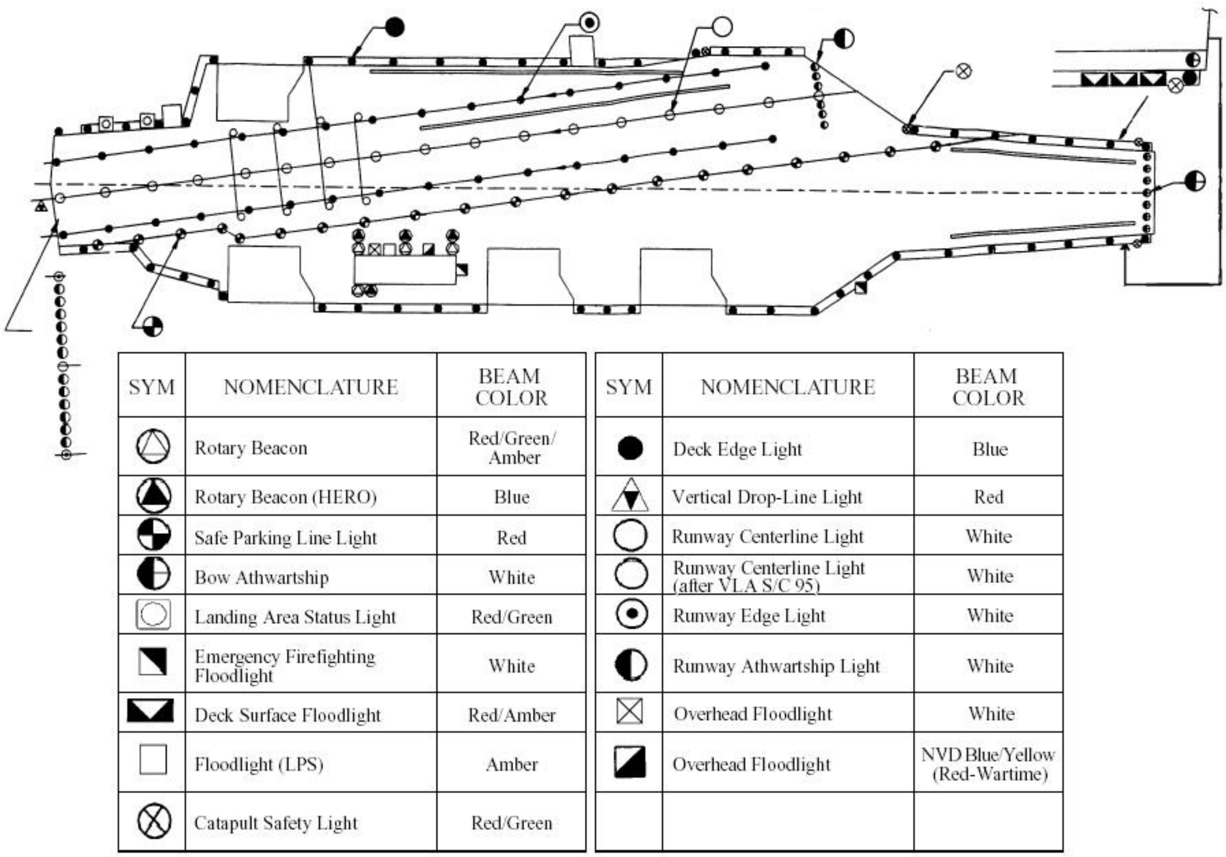


Figure 18. Flight Deck Lights[26]

The symmetrical location of all lighting fixtures as illustrated in Figure 18 above as well as the flood lamps used

26 NAVAIR 51-50AAA-1 003 00, Change 3 - 1 February 1999 Page 3. “Typical VLA Lighting Arrangement (CV/CVN)”

to illuminate the flight and hangar deck is also useful. In most cases, there is room either in the light fixture or on the light mount to support an added sensor. Even if the light fixture won't support the extra sensor, the sensor could use that light power cable.

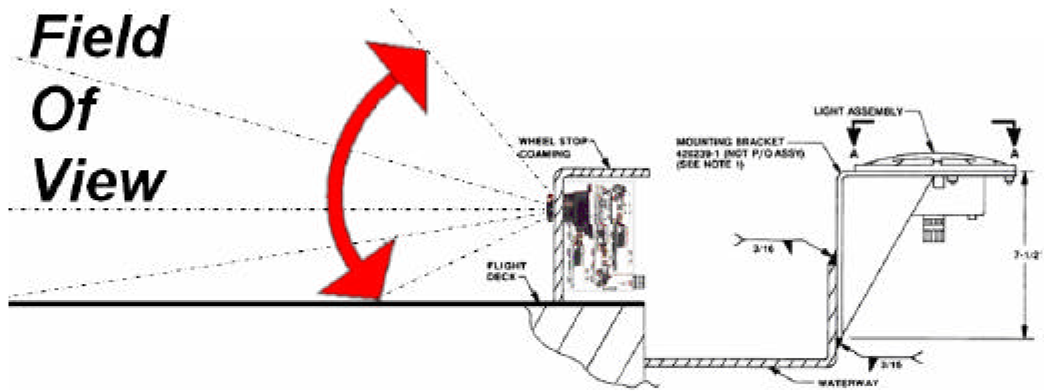


Figure 19. Visual Sensor Mounted at the Deck Edge[27]

For example, a CCD camera could be mounted in the wheel stop coaming at the deck-edge as depicted in Figure 19 or mounted below a floodlight high on the island as shown in Figure 20.

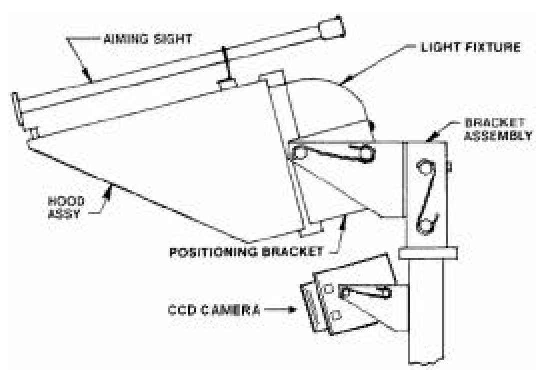


Figure 20. CCD Camera Mounted Below a Floodlight[28]

27 This figure was based initially on the Deck Edge Light Assembly 514610-1 (Sheet 1 of 2) in NAVAIR 51-50AAA-1 004 00,

28 Based on the Floodlight Assembly (PAR 56) 506829-1 (Sheet 1 of 3)NAVAIR 51-50AAA-1 006 00, Change 2 - 1 November 1995

## D. INTEGRATED FIXED FIELDS OF VIEW

Once cameras are strategically mounted, the various fixed fields of view can be analyzed and then integrated with other fields of view to systematically pinpoint dominant characteristics of the individual objects in relation to the fixed landmarks on the flight and hangar decks. Individual pixels in each fixed frame could be referenced to the fixed padeyes or deck lights introduced previously. If an object is near a known landmark, the system could interrogate the fields of view from corresponding cameras as shown in Figure 21.

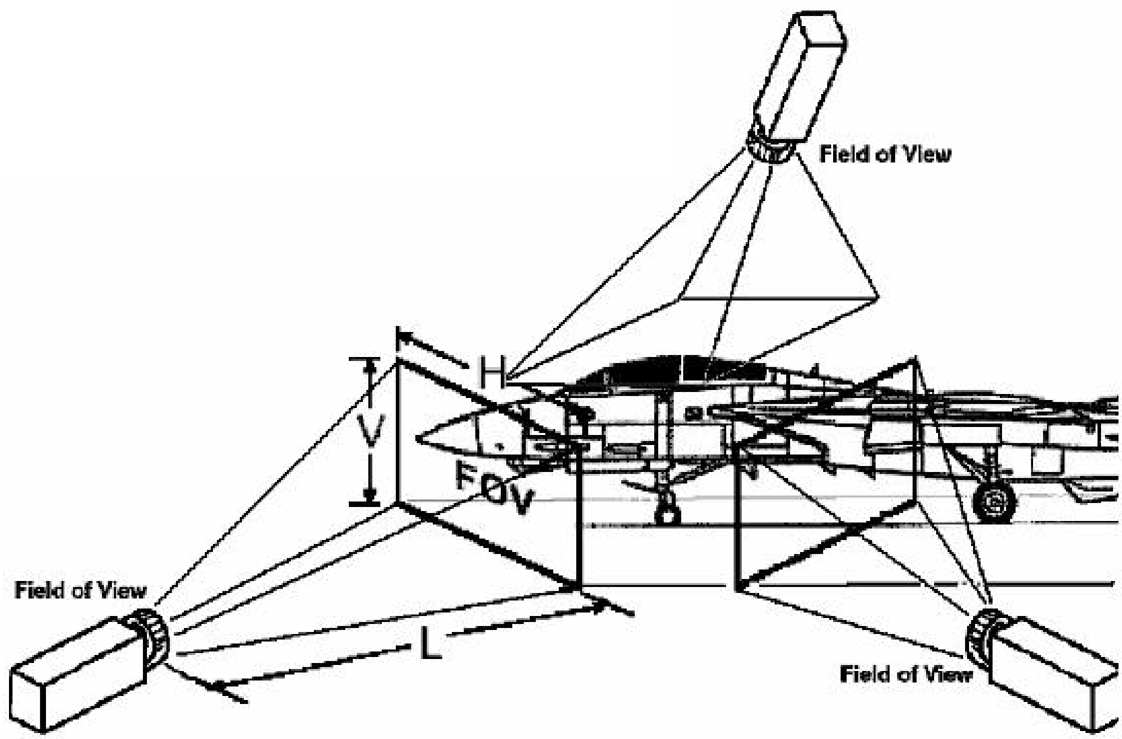


Figure 21. Integrated Fields of View

For example, if a fixed camera on the island recognizes an aircraft in its field of view, the system will know which general area the object is in. Line of sight from the island

camera will queue the system and estimate object location on a deck Cartesian coordinate grid as shown in Figure 22.

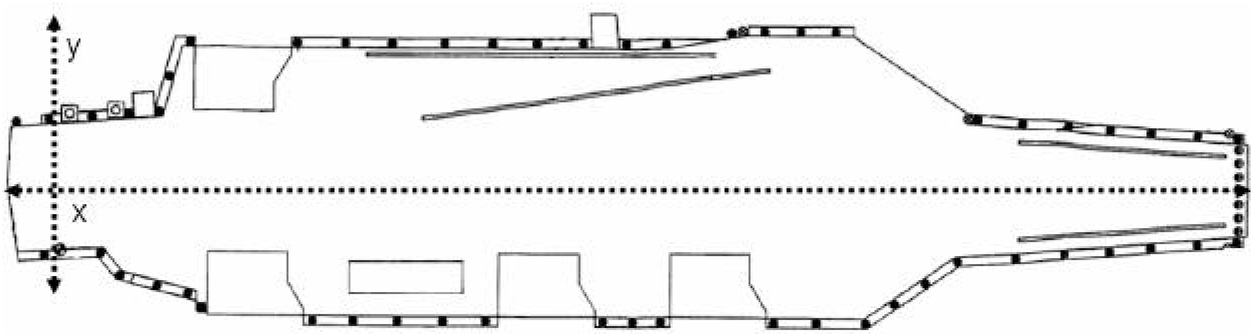


Figure 22. Flight Deck Cartesian Coordinate System

## E. OBJECT HANDOFF BETWEEN FIELDS OF VIEW

Another theory to reduce processing requirements could be methodology similar to cellular phone service. A cellular phone customer talks to a colleague on the phone while he drives down a highway.

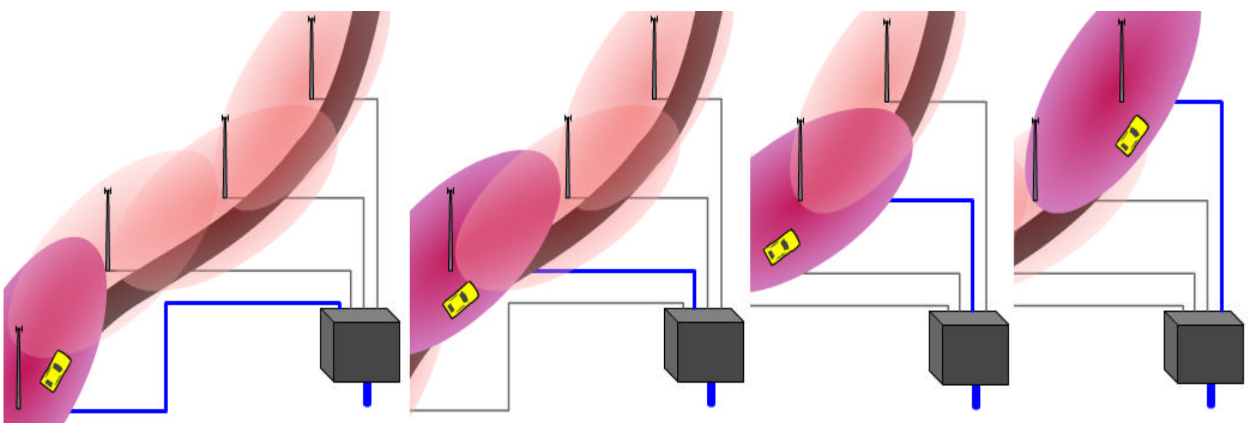

Figure 23. Cellular Signal Hand-off[29]

As shown in Figure 23, the call is initiated on the cell antenna with the strongest signal. As the caller proceeds down the highway, the signal to the first antenna becomes

[29] Graphics adapted from http://www.howstuffworks.com/cell-phone2.htm, June 20, 2002

progressively weaker but the same signal is getting progressively stronger at the second antenna.

Each antenna along the highway monitors signals within its range. The system determines when the signal is switched to the subsequent antenna. Seamlessly and without apparent signal interruption, the phone conversation is continued, but the signal is now from the second antenna.

The signal hand-off from antenna to antenna in the cellular phone example is an excellent analogy for how passive video cameras can be integrated.

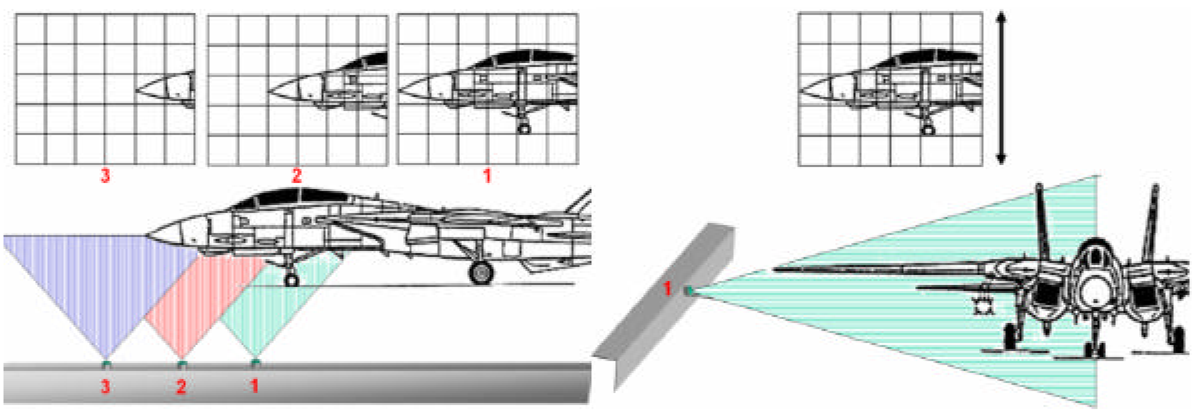


Figure 24. Field of View and Object Hand-off

As an object moves from field of view to field of view, the intelligent agent proactively monitoring an objects location and orientation will activate or capture the object in more than two cameras.

Two things can occur at this time. The system can then determine orientation of the object and identify both the visible and the unseen landmarks to determine the x and y coordinate and/or interrogate the appropriate camera, camera 1 in this case, as shown in Figure 24 above.

In order to reduce latency, the system could reduce the processing required to resolve that an aircraft has entered camera 1’s field of view as opposed to processing all fields of view where the aircraft isn’t. Because the camera is perpendicular to the flight deck, the exact “x” coordinate of the leading edge of the object could be pinpointed. The system could then use this information to minimize the processing required on other images in relation to this object. Specifically, if the object is an aircraft with known characteristics and dimensions, only the effected portion of each of camera 2 and camera 3 images has to be interrogated and/or resolved. Because the fields of view are fixed and the dimensions of the aircraft are known, the overlapping fields of view will require less processing to confirm the location of the object.

## F. FUNCTIONALITY DISCUSSION

For the purposes of this thesis, 30 frames per second will be sufficient to all the system to not only process but also integrate fields of view from several cameras. Considering how quickly a processor operates, time is essentially stopped for that 1/30$^{th}$ of a second. Because the computer can process information so quickly, results are theoretically displayed in “real time”.

Real time describes a human rather than a machine sense of time. It is a level of computer responsiveness that a user senses as sufficiently immediate or that enables the computer to keep up with some external process.

While it is outside the scope of this paper, simultaneous and parallel processing of images is possible and supports the

concepts of processing information in a complex environment in real time.

The real power of image processing and image integration initially includes the ability to subtract fixed portions of an image to isolate only those things that have changed or moved. The next is the ability to resolve images by comparing offset images.

This flexibility will facilitate the vision of reduced manned ships and possible limit the staffing needs on deck. In a future system, the aircraft on deck will either be remotely piloted or will have handlers directions to the pilot fed via data link to the pilots Heads-Up Display.

A very sophisticated system could differentiate between an aircraft and the technician riding a wing while the aircraft is towed to a new location?

It is conceivable that intelligent agents responsible to track the human could not only determine specific x – y coordinate, but triangulate the z coordinate (distance above the deck) as well.

Limb and torso orientation of the humans on the flight deck could also be discerned and considered in the decision support system as depicted in Figure 25. There is software available to track the exact orientation of the eyes, but this type of recognition currently requires dedicated cameras and a constant monitoring. Since flight deck personnel wear protective eye coverings, the most efficient method for this level of observation would be sensors inside the individual goggles.

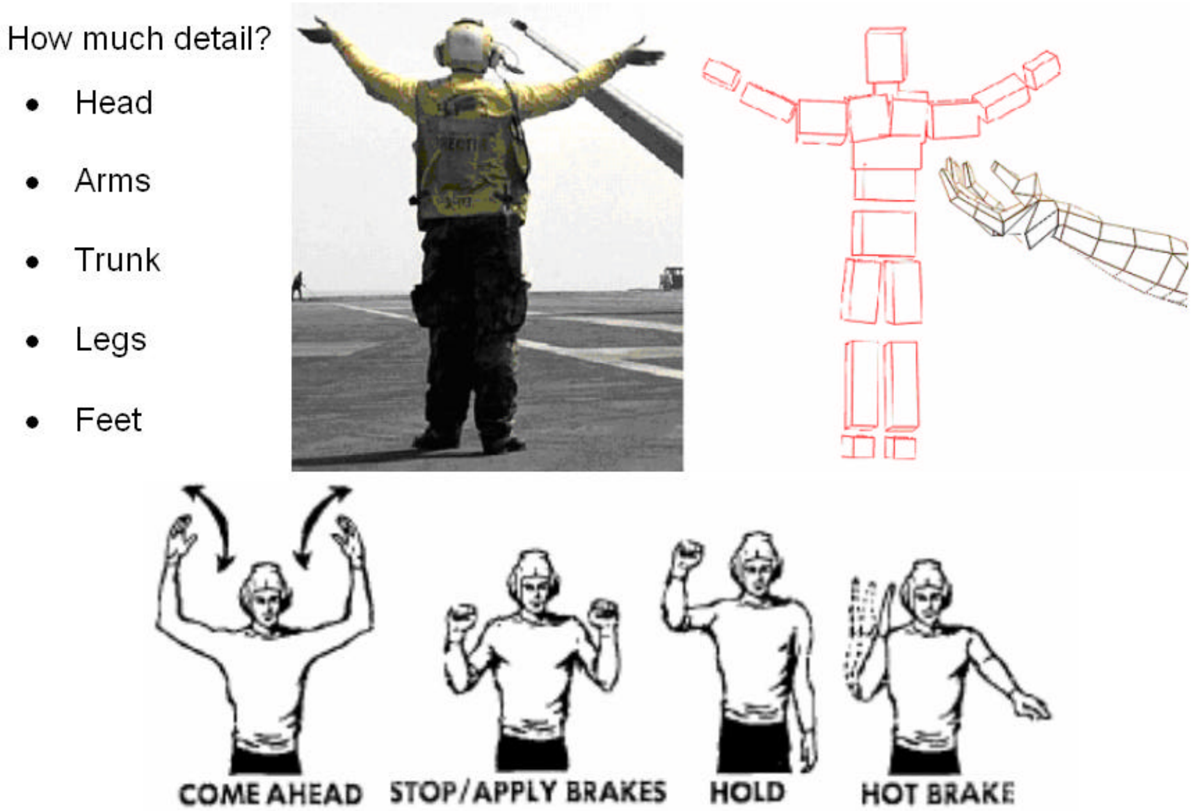


Figure 25. Actor Rendering and Hand Signals[30]

The system could interpret hand signals and body orientation. Then the system could anticipate a conflict and either notify a yellow shirt of a potential conflict or safety notification and give the handler updated information to adjust directions to the pilot or directly countermand the pilot over the tower radio.

This level of effort can result in heightened situational or environmental awareness. The system could interpret the orientation information of the actor and use that data to prompt that or another actor to beware of or look for potential danger

[30] Adapted from Aircraft Signals NATOPS Manual, NAVAIR 00180T-113

(i.e. look right, jet turning, jet blast envelope will cover your location).

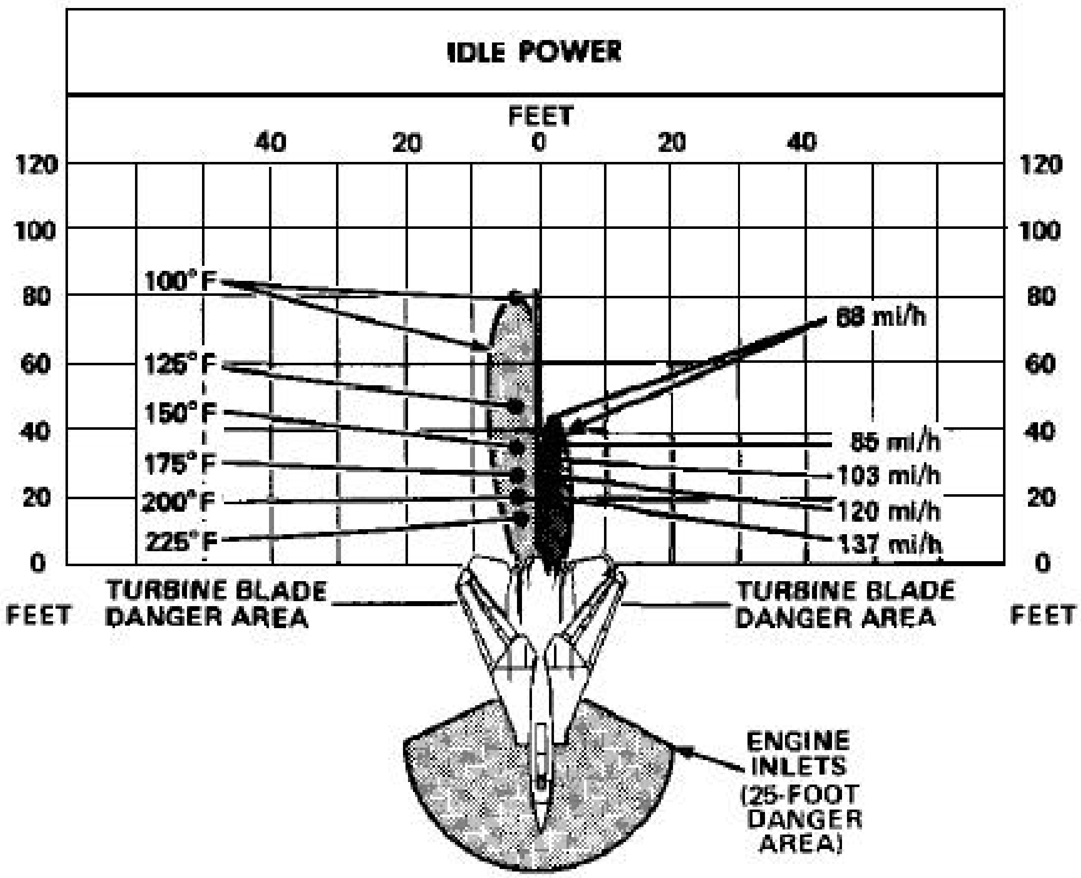


Figure 26. Idle Power Exhaust Temperature and Velocity[31]

As shown in Figures 26 above and 27 on the next page, jets exhaust temperatures and velocities parameters for all the various aircraft on deck can be cataloged in a system database. Idle through military power variations could be considered by the system and used to prompt actor notifications when potential conflicts were determined.

31 Adapted from NATOPS Flight Manual Navy Model F-14A Aircraft, NAVAIR 01-F14AAA-1

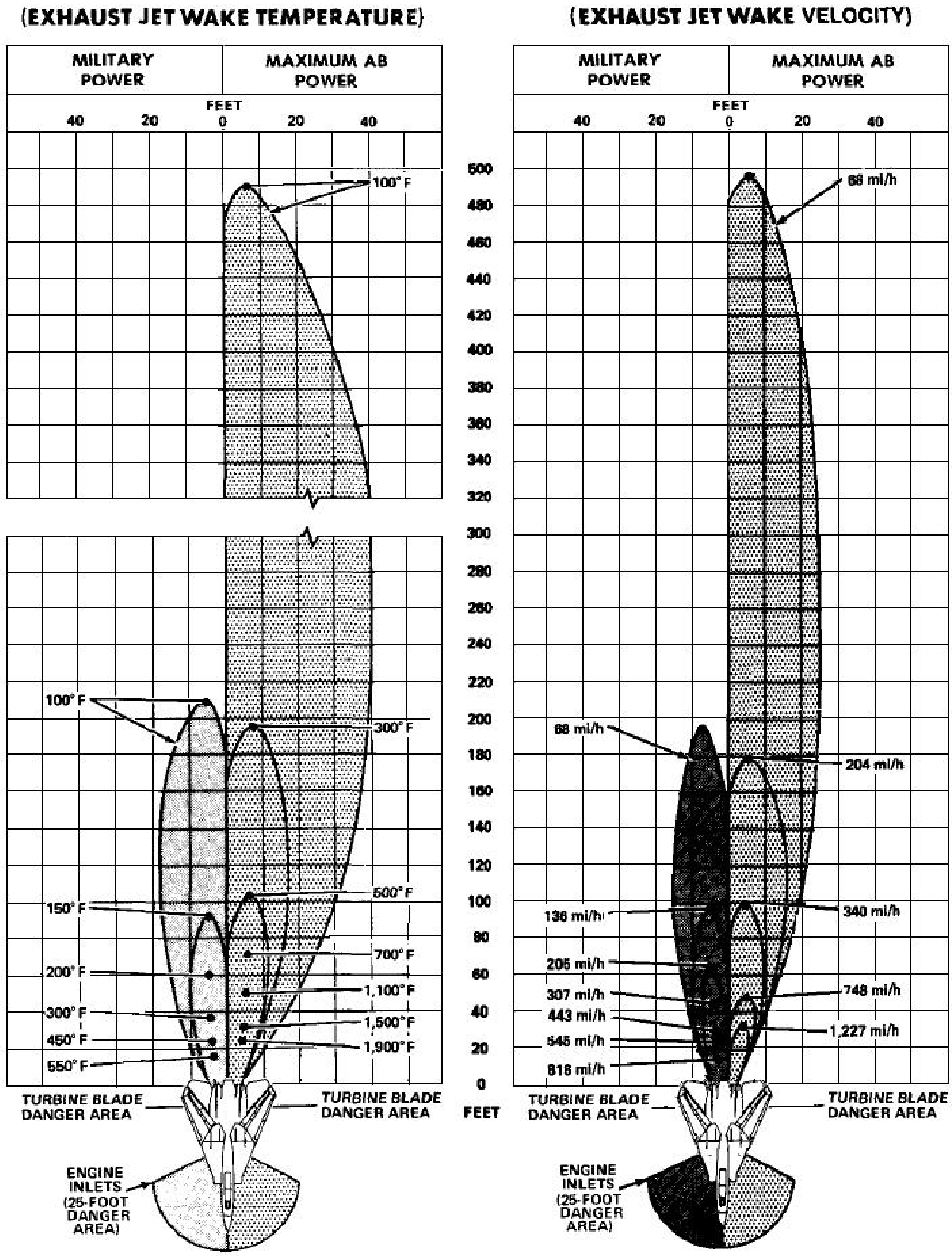


Figure 27. Exhaust Temperature and Velocity[32]

32 Adapted from NATOPS Flight Manual Navy Model F-14A Aircraft, NAVAIR 01-F14AAA-1

## G. PROCESSING REQUIRMENTS

When processing images, the first image is the default image ($IM_d$). All known fixed portions of that image will be immediately subtracted to streamline the bandwidth and processing requirements. This process could almost be completed at the camera itself.

The camera could be as basic as possible. Varying light might become a factor in the operational environment, but a camera with a fixed aperture and fixed lens with the minimal moving parts will result in less maintenance and higher reliability.

Software will be the determining factor using this strategy. For example, if the CCD has to be exposed for 1 microsecond for normal light, it may need up to 3 microseconds for the same equivalent exposure in low light. The longer exposure may cause blurring depending on what is moving and how quickly objects are moving in that frame.

The simple camera will have to work in intense and low light situations. Although cost will be a factor that will impact the final number and type of cameras used, operational flexibility and system reliability regardless of the ambient light will inevitably cause the organization to use cameras with Infra Red (IR) spectrum capabilities.

The CCD camera can take up to 30 individual images of the same scene every second, but for that 1/30-second, time stops. All cameras feed their respective image to fill their portion of the panoramic view of the flight deck.

The system, for example, would allow the Commanding Officer of the ship to move a virtual frame anywhere on the flight deck

using his browser and computer.  Figure 28 illustrates a possible camera numbering, positioning, and integration scheme.

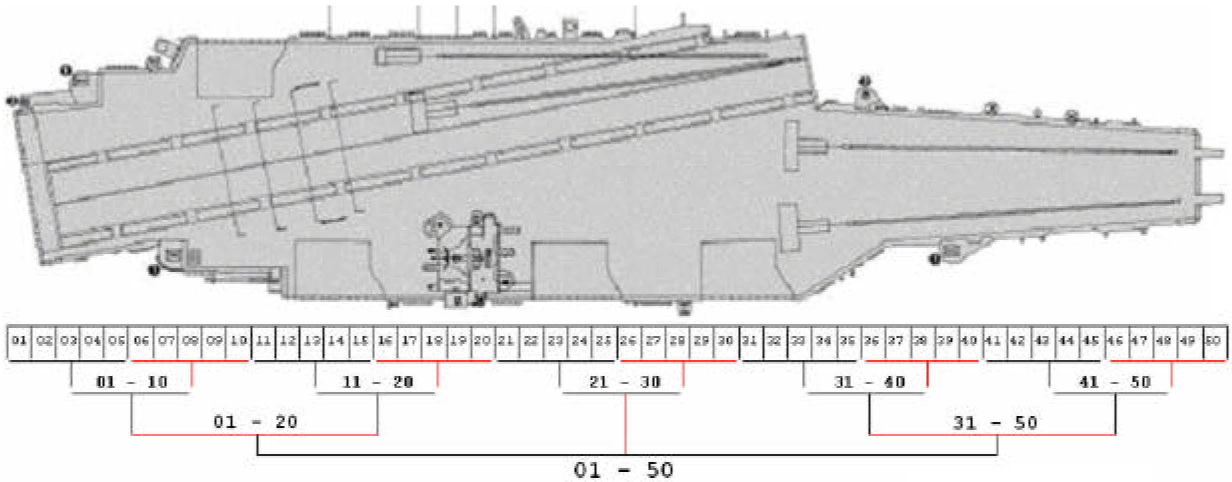


Figure 28. Camera, Position, and Integration Scheme

A joystick and frame icon over the silhouette of the ship would let the operator focus on any part of the deck.  Possible functionality would include freeze frame, replay, and enhanced capture for safety and mishap situations.

Parallel systems could tap specific camera feed for detailed streamed video in real time.  A second system could be used for instant replay.  A third could examine and anticipate movement and conflict information.

In a fixed microsecond, assuming the ultimate system could effectively capture, integrate, and store up to 30 panoramic images per second from fifty cameras, each camera required one Meg of memory or 50 Meg per panoramic shot and 1500 Meg per second.

A significant archiving capability would be required. While permanently archiving one hundred percent of the raw video is impractical, appropriate rules could be established to

archive significant parts of the raw footage that would document fires, crashes, and other casualties.

Another alternative is to determine if virtual simulation based on the real time rendering of objects when reenacting events that led up to a catastrophe would be acceptable.

## H. ALTERNATE SENSOR LOCATIONS

The optimal placement of sensors is yet to be determined. A single camera that could resolve the entire flight deck would be the easiest scenario, but that sensor would have to operate in all ambient light and weather conditions.

Two potential strategies could be Unmanned Aerial Vehicles (UAVs) or Mast Mounted sensors.

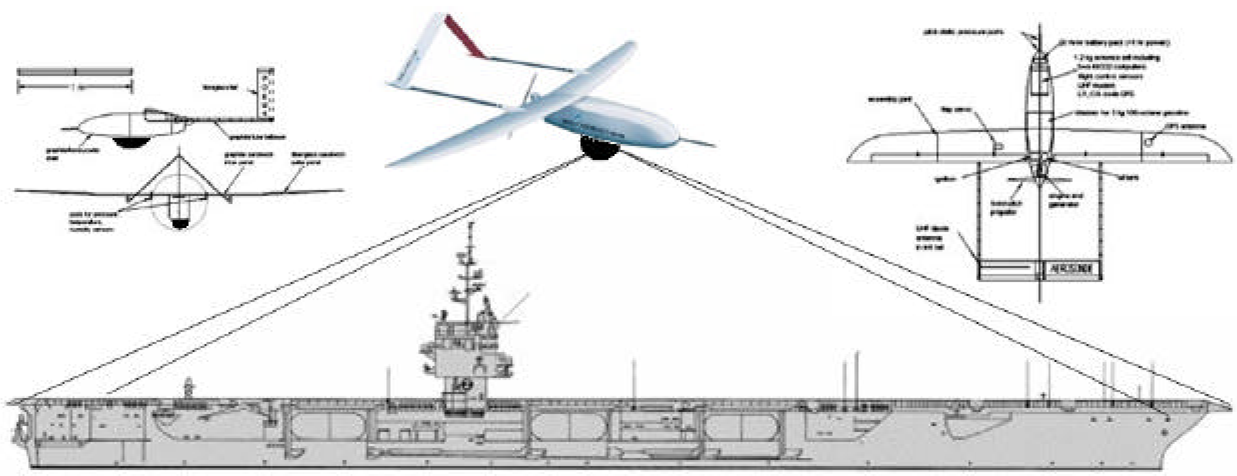

Figure 29. UAV On Station Above Ship[33]

The UAV featured in Figure 29 is the Aerosonde by Aerosonde Robotic Aircraft Ltd. The UAV is a small robotic aircraft developed primarily for long-range environmental monitoring and

[33] Graphic features the 'Aerosonde'. Illustration by Aerosonde Ltd. at http://www.aerosonde.com

surveillance. It has been developed especially for meteorological and environmental reconnaissance over oceanic and remote areas and in harsh conditions. Its economy and flexibility allows routine operations on a much wider scale than has been possible in the past and could possibly take station above the flight deck of a carrier. It has been extended to surveillance and other reconnaissance applications already.

> The Aerosonde is being deployed to fill chronic gaps in the global upper-air sounding network, to conduct systematic surveillance of tropical cyclones and other severe weather, to undertake offshore surveillance and agricultural/biological surveys, and to obtain specialist observations, such as volcanic plumes.[34]

This $50,000 gasoline engine UAV would normally operate at an Altitude of 20,000 feet and could travel as far as approximately 1800 nm. On station time is approximately forty hours with a cruise speed of 70 mph and a maximum speed of 85 mph. The optimal altitude and speed need to be determined. Slow flight characteristics were not available.

Limitations of this platform would be payload and bandwidth. Flying directly over the ship between two and three hundred feet would allow a CCD camera to effectively see all activity on the flight deck through one lens. Depending on optical characteristics, more than one camera would be warranted. An effective line of sight, high frequency signal would be required to relay the operational picture.

Sensors and required hardware to keep the UAV autonomously on station plus transmit the streamed video of the flight deck

[34] http://www.aerosonde.com, June 20, 2002

might impact the endurance of the UAV. Hardware and software needed to process the video should remain on the ship.

An advantage of the UAV directly above the ship is it could be used for passive surveillance of the surrounding area simultaneously with the flight deck. A disadvantage of this scenario is that an enemy might use the UAV to locate the ship.

The new CVNX class carrier will feature a smaller island with less radar cross section. A single mast with mounted CCD cameras would still be feasible. The mast would have minimal radar cross-section, yet simplify the challenge of capturing large quantities of streamed video feeding optical cable through the center of the mast. The lightweight cameras as featured in Figure 30 could be mounted high enough above the deck to allow a comprehensive operational picture.

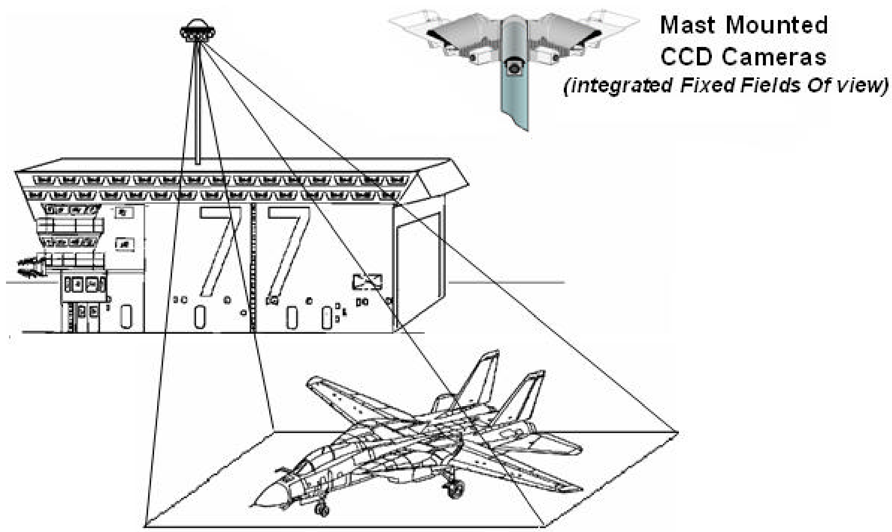


Figure 30. Mast Mounted Cameras

Commercially available hardware and software could be integrated with appropriate sensors on the flight deck to passively capture all object movement on the fight deck.

# VI. USE OF AGENTS

## A. TERMINOLOGY

Agents are programs that are able to respond to their environment and that have some effect on the environment by their actions. They carry out a task unsupervised, so they are characterized as autonomous. Intelligent agents take this one step further and apply some degree of what is termed "intelligence" to a task. The intelligence may be minimal but often will incorporate a degree of learning from past experience.

There are many ways in which software can learn. Two of the current technologies used for this are Neural Networks, and Case-Based Reasoning.

A neural network is usually an analytical tool that is designed to function the way neurons in the human brain receive, process, store, and communicate knowledge. Used to solve problems that typically defy formula-based analytical methods, neural networks produce answers based entirely on empirical evidence, or in human terms, through experience. This occurs frequently when there are large numbers of variables involved in the consideration of any one action in the model. The advantage to Neural Networks is that the software is adaptive or it has the ability to learn from experience. This is accomplished by programming a finite number of variable parameters that have distinct results in the initial program. The system is then able to use training algorithms in the following way[35]:

[35] http://www.statsoftinc.com/textbook/stneunet.html, June 20, 2002

> Neural networks *learn by example*. The neural network user gathers representative data, and then invokes *training algorithms* to automatically learn the structure of the data. Although the user does need to have some heuristic knowledge of how to select and prepare data, how to select an appropriate neural network, and how to interpret the results, the level of user knowledge needed to successfully apply neural networks is much lower than would be the case using (for example) some more traditional nonlinear statistical methods.

The use of neural networks is appropriate when any relationship between input variables and output variables exists, even when that relationship is very complex. They are "best used" for fault diagnosis and event correlation due to their efficient pattern recognition properties. They typically are used when there is a deep understanding of their domain. Additionally, they are an effective alternative when other methodologies fail. Neural networks are able to handle incomplete, ambiguous and imperfect data. This has considerable implications for our real-world application since it is realistic to predict that the standard mode of operation includes imperfect information.

Case Based Reasoning (CBR) is another methodology that is used to enable software to "learn". Case-Based Reasoning makes use of a library of solutions to known problems. The obvious issue here is what will happen when the library does not contain the answer to the question or problem at hand. This, in fact, is the single largest drawback to CBR[36]. Nonetheless, CBR is effective and has the following advantages:

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[36] Along Lin, Hewlett Packard Labs, Feb 1998, *A Hybrid Approach to Fault Diagnosis in Network and System Management;* page 2, http://www.hpl.hp.com/techreports/98/HPL-98-20.pdf

- While there are many other methodologies that may be it can solve problems within partially understood domains.
- It can reason by analogy efficiently.
- It can learn from new cases.
- Its knowledge representation is less restrictive.
- It allows faster knowledge acquisition.
- It can evaluate a proposed solution.

It is considered beyond the scope of this thesis to determine which methodology is most appropriate for use on the Digital Ouija Board. We merely mention it here to afford the reader a better understanding of what is meant by the concept of software that is able to “learn”.

## B. WHAT AGENTS CAN DO

The adaptive properties inherent to agents make them ideal for the use in this endeavor. Assuming the next generation Ouija Board and Air Department Data Management System proceed without a complete overhaul or consolidation of the many different databases, agents could be used to integrate the legacy parts. They could be used to locate, input and retrieve data from various systems. The “learning” would be useful in that the agents would be able to determine data paths and formats from previous “experience”. This would benefit the system by the increased efficiency in which the agents are able to read, write and display pertinent information from dissimilar programs or databases.

Use of agents is attractive because they are able to perform tasks for the user that greatly enhance the user's ability to work effectively[37]. Agents are always available and can act as the user's proxy in predetermined routine tasks when the user is otherwise engaged. When one considers the vast number of activities associated in everyday operations aboard the carrier, there is simply too much information for the humans involved to adequately monitor. An agent can act and react to situations quicker than the user could because an agent is able to observe its environment completely all of the time. It is not subject to human inattention or loss of focus. This thoroughness allows an agent to perform repetitive tasks without getting bored. Agents are also flexible. They may be specifically designed to adapt to changing circumstances or user preferences.

Some intelligent agents can also interact with one another. There is considerable research in this area, with many exciting possibilities. Some of the attributes of an intelligent agent are listed[38]:

- Autonomy: agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state

- Social ability: agents interact with other agents and (possibly) humans via some kind of agent communication language

- Reactivity: agents perceive their environment (which may be the physical world, a user via a

[37] Ian Dickinson, July 1998, *Human-Agent Communication*

[38] Björn Hermans, Thesis for the Tilburg University, Tilburg, The Netherlands, the 9th of July 1996, *Intelligent Software Agents on the Internet: an inventory of currently offered functionality in the information society & a prediction of (near-) future developments*; section 2.2.1 page 15

graphical user interface, a collection of other agents, the Internet, or perhaps all of these combined), and respond in a timely fashion to changes that occur in it. This may entail that an agent spends most of its time in a kind of sleep state from which it will wake if certain changes in its environment (like the arrival of new e-mail) give rise to it;

- Pro-activity: agents do not simply act in response to their environment; they are able to exhibit goal-directed behavior by taking initiative;

- Temporal continuity: agents are continuously running processes (either running active in the foreground or sleeping/passive in the background), not once-only computations or scripts that map a single input to a single output and then terminate;

- Goal oriented-ness: an agent is capable of handling complex, high-level tasks. The decision how such a task is best split up in smaller sub-tasks, and in which order and in which way these sub-tasks should be best performed, should be made by the agent itself.

These attributes are a lower level view of what an agent can do if properly designed and implemented.

The Digital Ouija Board has three distinct areas that will benefit from different sets of these properties. These are discussed in detail later in this chapter.

As previously mentioned, the Digital Ouija Board needs to enhance the current systems' capabilities and increase functionality of the existing Ouija Board from a static display to an integrated decision support utility. This has widespread applications for future operations on aircraft carriers, and might conceivably impact operations of the battle group or even

higher. In order to realize this potential the system must make full use of all the data that is currently gathered, but not necessarily readily available. One of the major systems goals for the Aviation Data Management and Control System (ADMACS) Block II upgrade is to integrate all of the disparate, “stovepipe” systems so that all the data is shared across systems to give the users the complete data visibility that is required[39]. Since the data used in the aforementioned systems was developed by-and-large as stand-alone systems, little consideration was given to a consistent data structure. In order to accommodate future integration of these systems, there needs to be a way to interface with other systems data, such that new functionality will not interfere with the established processes.

Interviews with the researchers at Lockheed’s Advanced Technology Laboratories (ATL) have confirmed that when unknown or varying data structures exist it is the ideal situation to use agents. Their assertion is that agents are only concerned with the actual data and not the data structure. Furthermore, agents have the added benefit of speeding up database processes, which is counterintuitive. It is logical to assume that an additional layer of obscuration would cause the system response times to increase. Apparently, agents are able to decrease response times for data manipulation. The explanation for this is summed up in the following quote by one of the ATL researchers:

> …a mobile agent is basically a software program that can transfer itself to multiple machines while executing. Thus, it has the ability to transmit code to another machine, such as the case of a query to a database for some specific item. The code is the

[39] *ADMACS Program Block Upgrade* PowerPoint presentation from NAWC Lakehurst

logic to find the right item in the (database). Since the logic to select the proper item is brought to the machine, the agent can continue to search, while local to the database, rather than transmitting data multiple times while searching for the proper (database) entry. Basically, the cost is the one time travel of the agent code versus the cost of multiple transmissions of data as in a remote query. Thus, in contrast to the client-server model, this provides a beneficial bandwidth savings.

In essence, the agent is able to precipitate a distributed computing scenario where more than one machine (or processor) is working on a particular problem. Thus it appears that the use of agents for the interactions across the multiple legacy systems may be not only appropriate, but also potentially very beneficial.

This benefit is fortuitous since we feel it is unlikely that a complete overhaul of all the existing systems will occur in the short-term. We firmly believe that there are other mitigating circumstances that would suggest that the complete overhaul of the existing systems would be an optimal solution. Our opinion is based on the observations that we have made on how individual programs today are managed with little, if any, regard to how their piece of the puzzle fits into the "big picture". The primary problems will all come back to the scope and funding of these individual systems.

These legacy systems exist as a product of individual "solutions" devised to answer specific needs. This appears to have been a prevalent approach to application authoring from fifteen years ago. For example, no one wanted an office suite that did word-processing, spreadsheets, database and presentations – indeed; no one even fathomed all of these things together. Yet, integrated "products" would become the standard

way that most everyone purchases office automation software today. The benefits of an integrated suite of programs are that the parts are designed to work together. If they did not, customers would not be enticed to purchase an integrated product that was less capable than the individual parts.

The issues with the current stovepipe systems are that they are predominantly dated systems that were only designed to address the original users' concerns. It is difficult and costly to keep many of these hardware-dependant systems functional. We did not observe any attempts to validate the dated requirements that these systems where originally designed to address. We did observe engineers writing requirements for what the updated system ought to be. Clearly, this is a case of the tail wagging the dog. The "Fleet" users should be telling the engineers what is needed, not the reverse. A more effective requirements modeling process is needed.

Another observation is that the requirement to make the data available for other systems to use was apparently not considered. Therefore, we endorse an approach that would require a bottom-up requirements review that clearly defined the needs of all of the Air Departments (Flight Deck Control, CVIC, Weapons, Fuels, the squadrons, Air Ops, Pri-Fly, etc.). These "needs" could readily translate into data fields in one master database and would conveniently facilitate visibility that we assert is needed in order to realize the efficiencies discussed in this thesis. As previously mentioned, our "B Plan" would utilize the existing systems as they are with agents enabling the interconnections between the systems.

There are other aspects to the overall data / knowledge management issue described in this thesis. The use of agents

for the control of and integration of the sensors is seen as the enabling technology. Our intention is to further describe how agents could be used to facilitate this and other vital functions.

Lockheed Corporation has done extensive research and development in the field of software agents and has categorized them into three distinct groups[40]:

> The Advanced Technology Laboratories developed generalized notions of three of these capabilities: information push or agents automatically send information to other agents or entities that may need it; information pull, where agents retrieve relevant information from distributed sources; and sentinel monitoring, where one or more agents persistently checks for an event or existence of a condition and reacts to its occurrence.

This agent classification is descriptive of what we envision the new system of systems routinely executing. Agents are able to provide database connectivity when users require information. They also may be used to retrieve data automatically and perpetually, modify date if required, and display summarized data in the appropriate form.

Lockheed discovered that they could use the agents to make complex queries from disparate databases. In fact, they found the use of agents to be beneficial to this activity since the agents allowed them to specify what they called "high level concepts" vice exact database schemata[41]. The applicability for the Digital Ouija Board is that this ability will permit the interactions of the system with existing legacy / stovepipe systems *without regard to the data structure.*

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[40] Susan McGrath, PhD; Daria Chacón; Kenneth Whitebread, PhD; *Intelligent Mobile Agents in the Military Domain*, pgs 1-5

[41] IBID

The sensor portion of this project could also benefit from extensive use of agent technology. Current efforts to provide sensor fusion focus on bringing radar, infrared (FLIR) and other combat systems information together in order to provide enhanced target tracking. This same weapons application logic could be ported for the use of multiple, but similar sensors tracking the same information, but from different vantage points. This fusion would enable multiple sensors (presumably CCD cameras) with different fields of view to correlate their images, or tracks; to verify that what one camera “sees” is the same aircraft that another camera is tracking. This merged data not only enforces the certainty that a track is correct, but it works integrally with the display agent responsible for depicting the correct track information on screen.

Another important research effort sponsored by the U.S. Defense Advanced Research Projects Agency (DARPA) is the Control of Agent-Based Systems (CoABS). This research program has classified four distinct agent type of particular interest to the military[42]:

> …those that are aimed at complex problem-solving; those that find, filter and present information for users; those that provide services to other agents to help them cooperatively solve complex problems; and those that provide translational services between agents using different standards, communications protocols, languages, etc

The proposed system would be a large-scale effort in terms of size and complexity. It remains to be seen if the actual number of agents to enable such a multifaceted system would be considered a large-scale effort by DARPA’s standards. There may only be a relatively small, finite number of agents that are

[42] IBID

needed, however, these few agents would likely be reused extensively throughout the system since there are many similar objects and redundant actions associated with aircraft handling.

In concept, the system could be comprised of interacting agents from all four groups, and could offer new capabilities that are now beyond the realm of traditional software design. The system will require a dynamic infrastructure that could provide these capabilities and would purposefully direct software developers to design smaller pieces of code that would primarily function on solving problems through mutual interaction, rather than independent systems duplicating functions that are better provided by other programs or by a hybrid system.

The Digital Ouija Board could make use of many common components, thus keeping it aligned with other military applications, as described by the Lockheed group. The significance of this should be emphasized since we are endeavoring to automate a system that has been in existence for over fifty years. The operators will want assurances that the technological solution is sound, tested and reliable. Using tried and true components, we are able to assuage some of their initial fears.

An added benefit to the Navy is to discover which commercial elements are working in the field of agent development so that they may be consulted on work like this, or for other systems. Our discussions with the ATL make it abundantly clear that ATL is a prime candidate for consideration.

In order to maximize the Digital Ouija Board’s utility for as many users as possible it will have, or at least should plan

future expansion to include, the capability to interact with multiple users as “targets” or “actors”. What is meant here is the aircraft director on the deck or the yellow gear driver will be able to receive information from the system to alert them to a particular condition. In the safety realm, this could be used to alert actors of an impending collision or an individual actor who is about to walk into a danger area (turning propeller, or jet blast zone). To facilitate this type of functionality, the system might use what Lockheed has labeled an *Information Push*.

Developed for DARPA’s Small Unit Operations (SUO) program, the “Information Push” was created to enable the system to first locate an individual actor, and then push critical information to that individual, team members, or higher echelons directly above the actor in order to prompt a critical response (be it an answer to a query or a warning to the individual). Other agents work in tandem with the push agent to optimize the operation.

An *Analysis Agent* determines who needs specific information. This feature ensures proper delivery yet minimizes the bandwidth requirements for the notification by eliminating traffic that is not required, compared to a more general multicast transmission. A *Delivery Agent* is employed to keep track of the nodes, actors and delivered information. If the delivery agent determined none of the targeted actors received the message, it can activate an additional agent or initiate additional actions that would perform a contingency action as needed.

We envision the following scenario as a graphic illustration of how this all works: A yellow shirt directing an aircraft while another flight deck crewman inadvertently walks into the path of a moving aircraft, or turning propeller. The

“safety watch” capability of the system could anticipate the conflict and respond by activating a specific agent programmed to immediately notify that crewman of the impending conflict. The analysis agent would determine who needs the information and the delivery agent would ensure the message was delivery to that individual. Should the delivery agent sense a delivery failure, another agent is activated that would elevate the warning and attempt to deliver it to other crewmen near the at-risk crewman? In the event the crewman is still not responding, another agent would notify the Air Boss to direct his attention to the imminent problem.

This type of agent use looks promising for the type of scenario described. There are countless other uses for this technology, especially as more flight-deck personnel are connected to the communications and information network, either via headsets, PDAs, or other wireless computing devices that would enable alerts or notifications.

Since the proposed system is primarily interested in tracking the position and movement of a fixed number of aircraft and displaying associated information, we must consider the timeliness of any information system that must be real-time. Ideally, we want to be able to track more than just the aircraft. The system has considerable safety applications that will be most effectively realized only when all objects on the deck are tracked; aircraft, people and support equipment.

Now the problem of system updates for real-time display plus the added requirements that multiple agents making countless data calls to many independent databases becomes much more significant. The system must take the throughput,

bandwidth, storage, memory and processing capabilities into consideration.

A factor here will be to what extent these multiple software agents have on the performance of the system as a whole as it relates to the aforementioned constraints. This problem is not unique to our proposed system and has been investigated by the CoABS project. Their findings indicate that a system can use upward of ten thousand agents before realizing any performance degradation. Furthermore, only a minimal degradation was observed as the number of registered agents increased[43].

In many agent applications, one of the compelling reasons that an agent will visit a computing node is to utilize the resources at that node. There are three important points to note. First, to conserve bandwidth the system should migrate as little code with an agent as possible. Second, the code or logic needed to exploit the resources at the node will usually be the same for all agents. Finally, it is desirable to separate the implementation of these resources from the implementation of the agent application.

The researchers at ATL describe an environment with existing nodes as being a primary consideration for the application of agents. As such, the current "system" aboard US Navy ships for the Ouija Board, and for the larger "system" which includes all of the associated Air Ops data systems (be it a computerized system, a grease board or a clipboard) appears to be the perfect candidate for the application of agent technology.

43 Martha L. Kahn and Cynthia Della Torre Cicalese, *CoABS Grid Scalability Experiments*, pg 1

Consider an agent-based database application where the data resources are distributed among several computing nodes, as depicted in Figure 31. In a heterogeneous database environment, the code needed to query a database will not be the same at all the nodes. In fact, the actual implementation of the databases at these nodes may be changing. In such situations, it is better to package the code needed to access these resources into a separate component, which remains at the node, known as servers. It is beneficial to have a common interface between the agents and the servers that offer similar services at different nodes, even though the servers may differ in their implementation. This keeps the agent machine-independent.

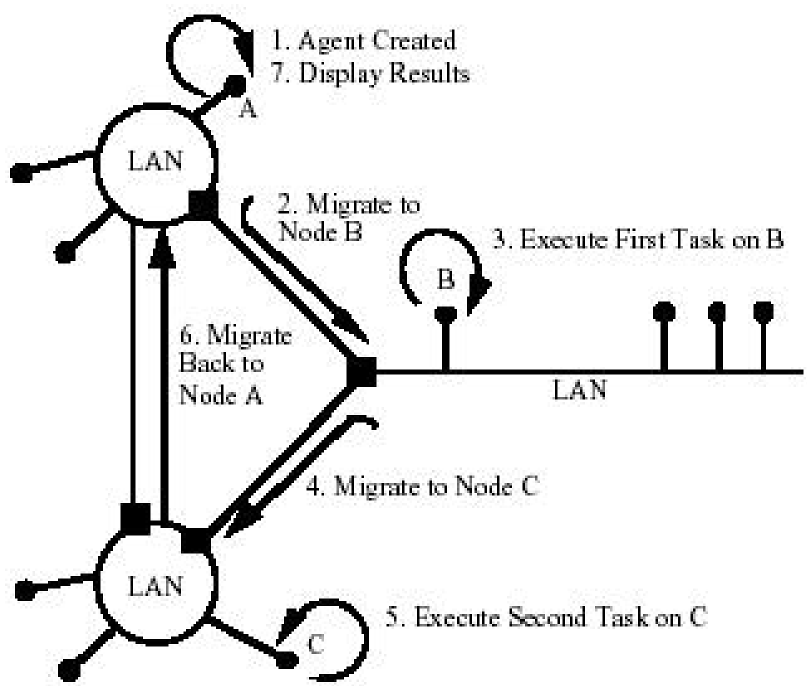


Figure 31. Agent Distributed Amongst Nodes

As previously mentioned, one of the benefits of using agents is that they are schema independent. This is

advantageous since information is the aspect of the database that users are primarily interested in, not the format of the data. Agents, therefore, are able to reuse their code to extract data from different types of databases without having to know anything about the individual schema.

Figure 32 illustrates an agent performing a database query at one node hosting a DB-2 database and then migrating to another node hosting a Microsoft Access database.

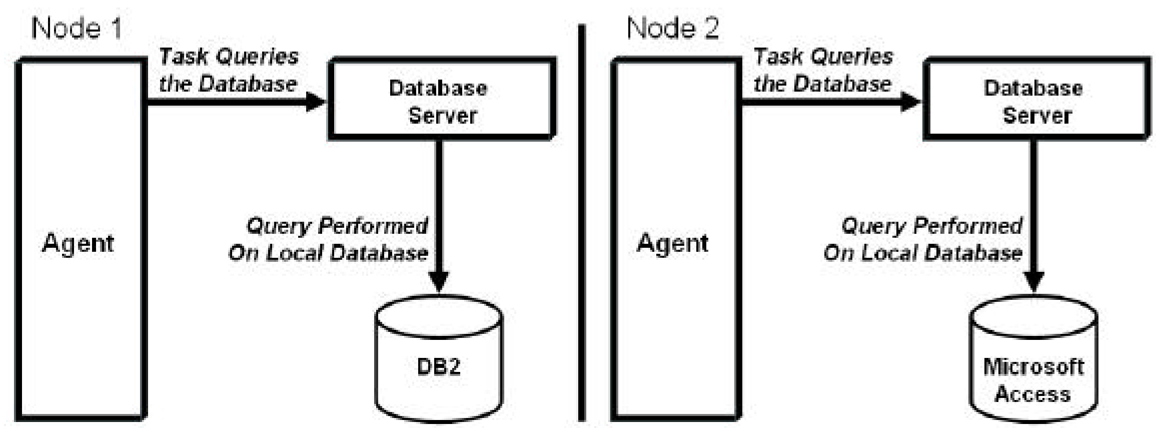


Figure 32. An Agent Performing a Database Query[44]

> The agent uses the same interface on each server to execute a database query even though the server's implementation is different at the two nodes. We can now piece the agents, tasks and servers together. An agent executes a task at a node. The task may access servers to exploit resources at that node to achieve a certain goal. If the interface to the servers is the same across various nodes, the same tasks may be used with different resources.[45]

One of the agent function requirements is based on the peer-to-peer wireless connection for users (assumed to be

44 Russell P. Lentini, Goutham P. Rao, Jon N. Thies, and Jennifer Kay; *EMAA: An Extendable Mobile Agent Architecture*, page 3, 1997

45 Ibid

supervisory personnel at this time) on the flight deck described in chapter five.

The previously mentioned Limited Objective Experiment conducted at the Naval Postgraduate School provided insight into a potential problem that could cause a detrimental effect to the wireless network. When a wireless device left the range of one antenna the applications on the wireless device would lock up. This was attributed to application robustness and resulted in excessive packet loss. A device required re-initialization of the application on the network once it was in range of another access point. To avoid this situation it will require the system to keep track of the devices that are currently on line. A dedicated design effort will be required to keep nodes connected so that the applications do not perform as an effect of packet loss. This will require devoted monitoring by an agent that will be both robust and mobile to monitor the signal strength and location of an individual user. This appears to be a logical parallel to cell phone technology that enables the phone to connect with the strongest transmitter in its environment.

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# VII. AIRCRAFT HANDLING DECISION SUPPORT REQUIREMENTS

## A. INTRODUCTION

If the United States strategically plans to use military air power to overwhelm enemies with “Rapid Decisive Operations”, advanced dynamic collaborative tools and intelligent agents will be of paramount importance. These tools and agents will be critical not only coordinating the individual flight deck in execution, but especially during the deliberate planning phase by coordinating several aircraft carriers in different areas of responsibility against the same threat or adversary.

As the battle space becomes more dynamic, aircraft handlers will require timely and accurate information to process, analyze and decide, and then disseminate it quickly to subordinates on the flight deck to initiate a quick and decisive action.

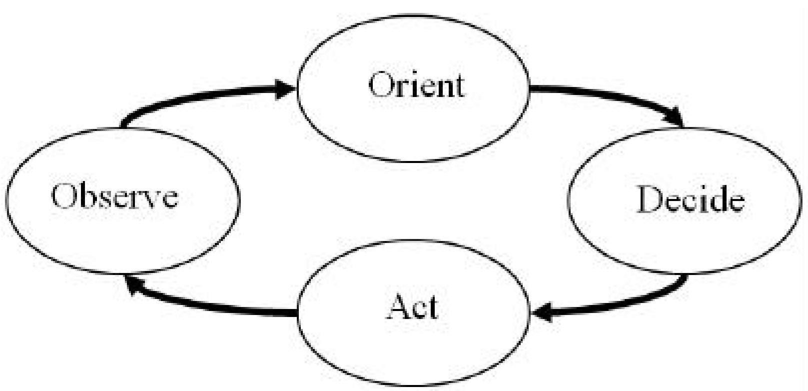


Figure 33. “Observe-Orient-Decide-Act” (OODA) Cycle[46]

The ability to rapidly exchange information around the battle group and throughout the operational space will force the sequential, linear planning of the past to give way to

[46] *“A White Paper for Joint Interactive Planning”*, United States Joint Forces Command, Joint Experimentation, Concept Division (J-92), 10 May 2000

simultaneous, interactive planning, which will greatly affect the tempo of execution. Simultaneous, parallel planning will shorten the “decide” component of the “observe-orient-decide-act” (OODA) cycle depicted in Figure 33 and will allow the Air Wing to gain significant leverage over the enemy. The result will be improved flight deck command and control and directed unity of effort.

Information technology has already significantly changed the world in which military forces must operate. This technology, when combined with innovative organizational change and progressive business processes, can directly impact how Air Operations (Air Ops) plans and executes assigned missions. The Aircraft Handling Decision Support System (AHDSS) will combine existing functionality in both ADMACS and ISIS, yet maximize the utility of emergent technology deliberately over the life of the system.

## B. INTERACTIVE PLANNING AND COMMAND AND CONTROL

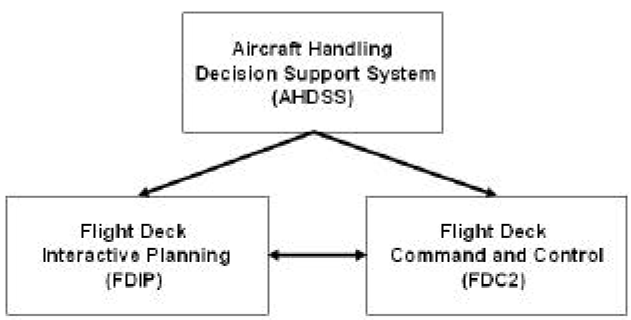


Figure 34. Initial AHDSS Structure

The AHDSS should be approached as flexible collection of interfacing tools. The initial AHDSS structure, as shown in

Figure 34, introduces Flight Deck Interactive Planning (FDIP) and Flight Deck Command and Control ($FDC^2$) subsystems.

This structure is used to help redefine and restructure existing business processes so available technology can be used to not only automate manual tasks, but also help the organization evolve to a new operational standard. This shift is critical because operational demands often exceed operational availability. This emphasizes the further requirement for planners and operators to process exponentially larger quantities of information rapidly and effectively.

Planning and execution are the two actions that synchronize and sustain the application of air power. Therefore, the purpose of all the aircraft carrier functions, processes, and components are unified in a common effort. Air Ops must be able to rapidly exploit information from a wide range of traditional and non-traditional sources in order to integrate fully each asset that facilitates launching and recovering aircraft on aircraft carriers.

This interactive planning is introduced and examined in the context of Decision Support Systems and then Air Wing Operations delineated in the context of Command and Control.

Rapid Decisive Operations (RDO) is a concept to achieve rapid victory by attacking the coherence of an enemy's ability to fight. It is the synchronous application of the full range of our national capabilities in timely and direct effects-based operations. RDO on the carrier could employ asymmetric advantages in the knowledge, precision, and mobility of the air assets against an adversary’s critical functions to create maximum shock and disruption, defeating the adversary’s ability and will to fight.

## C. FLIGHT DECK INTERACTIVE PLANNING (FDIP)

Flight Deck Interactive Planning (FDIP) is defined as bringing together, through information technology, the right equipment, people and information at the right time for planning an operation. The result of the planning provides a shared awareness of the commander's intent maintained throughout the battle space. Having the right information at the right time will empower the Handler on the aircraft carrier to take control of the flight deck space and facilitate the battle group's ability to maintain the initiative.

The FDIP intends to improve the speed of command and unity of effort. The FDIP will allow supporting staffs and other resources, both those on the ship and possibly those separated by geography, time and organizational boundaries, to allow all of the players to collaborate, develop, and coordinate unity of effort in planning and execution. By rapidly exchanging information of the commander's intent and plan throughout the battle space, FDIP could allow for simultaneous, parallel planning through force echelons of command, greatly improving the speed of command and reducing aircraft ordnance on-target response time.

## D. FDIP ELEMENTS

The FDIP concept is made up of three primary elements including an Interactive Flight Deck Planning Group (FDPG), an adaptive, tailored planning process, and a dynamic, shared Air Plan space as depicted in Figure 35.

The FDPG is a virtual collaboration environment that allows the co-location of applications, data, and users in a shared, persistent workspace.

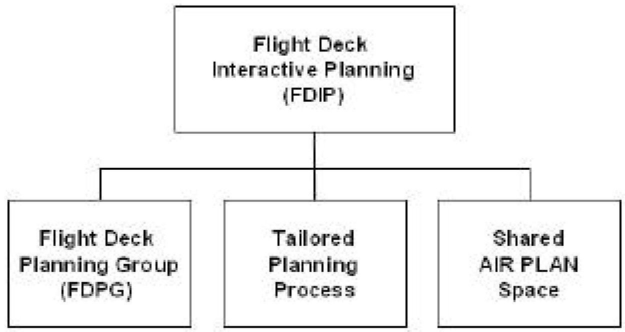


Figure 35. FDIP Elements

An adaptive, tailored planning process integrates the Interactive FDIP and the final Air Plan in a distributed environment that could replace deliberate or crisis-action planning by using alternative time and mission tailoring methods.

A dynamic, shared Air Plan is the product of a continuous and developing planning process that evolves with the mission using information technology to provide effective presentation of recent (or real-time) information to ship's company, the Air Wing, the CVBG Staff, and other commanders.

The strength of this approach is that the time traditionally needed for individual elements to realize a conflict in the execution of an air plan can be reduced or eliminated.

The major decision support functions of the FDIP are:

a. Collaboration
b. Course of action (COA) development and analysis
c. Course of action selection

Once the basic operations plan is decided, further refinements will encompass the following supporting plans to the last minute. Sub-categories are included to reflect greater detail.

The Air Plan

- Equipment
- People
- Supplies
- Ordnance
- Fixed and Rotary Wing Aircraft

The flight deck support plan, as described in this paper, is comprised of six main support sections identified below. In addition, for best support, the Handler might attempt to maximize these within the principles of logistics, such as responsiveness, survivability, sustainability, attainability, simplicity, flexibility, and economy. These sections are:

Flight Deck (V-1 Division)
Catapult and Arresting Gear (V-2 Division)
Hangar Deck (V-3 Division)
Aviation Fuels (V-4)
Squadron Maintenance
Ship’s Services

## E. FLIGHT DECK COMMAND AND CONTROL

Flight Deck Command and Control ($FDC^2$) is the part of the AHDSS system that will change as technology becomes available. This subsystem will coordinate the communication between the various nodes in the flight deck network. A node in the $FDC^2$

context will be any sensor, person, or object that feeds information into the FDIP. Further, the FDC[2] will encompass the tools used by nodes on the flight deck or in the ship for heightened situational awareness.

## F. THE ROLE OF DECISION SUPPORT TOOLS

The Decision Support System (DSS) tools could provide enormous assistance with providing the Air Boss, Handler, and other responsible actors with quick and relevant information to control the flight deck space. DSS tools would provide enormous support to help in deciding some planning factors such as:

- Characteristics of the flight deck:
- Climate, weather, EMCON condition;
- Resources available;
- Ship's and Aircraft Periodic Maintenance Schedule;
- Expected interference with launching/recovery functions
- Catapult readiness.
- Tasks requiring special ordnance, supplies and equipment.

## G. DECISION SUPPORT SYSTEM ELEMENTS

Decision Support System elements will include components of the DSS and also consider the decision styles of the traditional users of the system. These elements will be used as the initial criteria for evaluating both the effectiveness of intelligent agents and the various collaborative tools that might be used to support flight deck operations. If the ultimate system architecture is designed to adapt to the users, the decision styles may change, but the DSS components will not. The

intelligent agents will adapt, but this will be transparent to the user.

The DSS components are shown in Table 2:

| **Description** | **Action or Issues related.** | **Examples** | **Area of usage** |
|---|---|---|---|
| Data Management System | Retrieval, storage, and organization of the relevant data for a decision. | Db, DBMS, Data repository, and data query facility | Items, fuel capacities, ordnance, etc. |
| Model System | Performs retrieval, storage, and organizational activities for quantitative analysis | Mb, MBMS, Model repository, model execution and model synthesis processor | Time schedules, log requirements, locations, priority, etc |
| Knowledge Engine | Problem recognition and generation of interim or final solutions | The "brains" of the outfit. Data and models come together | Coordination of items and efforts |
| User Interface | Easy access and understanding for manipulation of the DSS | Interface manipulation | System interface |
| DSS User | Skill set, motivations, knowledge, domain, patterns of use, and role within the organization. | Computer skills and flight deck information | Section reps, planners and/or assistants |

Table 2. Decision Support System Components[47]

[47] *"Decision Support System to support Logistics for Joint Interactive Planning for Landing Force Operations"*, Mark Harrington, LT Andy Wiest, LCDR Harold Valentine, LCDR Tim Thate, June 2001

The Decision Styles of the various components involved in the decision are described in Table 3:

| Decision-Maker | Style | Main personality traits |
|---|---|---|
| Air Wing Commander | Directive | Expects results, aggressive, communicative |
| Air Boss | Analytical /Directive | Wants best answer, Innovative, Uses great care, Great data, Expects results, Intuitive, Communicative |
| Handler | Analytical /Directive | Wants best answer, Innovative, Uses great care, Great data, Expects results, Intuitive, Communicative |
| Flight Deck Officer | Directive | Expects results, Aggressive, Communicative |

Table 3. Decision Styles

## H. AIRCRAFT HANDLING INFLUENCE DIAGRAM

The DSS for the flight deck is envisioned as a tool to more rapidly and dynamically allocate scarce resources in support of the mission. This view is intended to be high level in nature and specific quantifications have been avoided to give the “Big Picture”.

The Aircraft Handling Influence Diagram as shown in Figure 36 begins the process of categorizing the information managed and decisions supported within the system. The Aircraft Handling DSS would be beneficial for further study and possible implementation to provide coordination between the requirements and the capabilities in greatest efficiency.

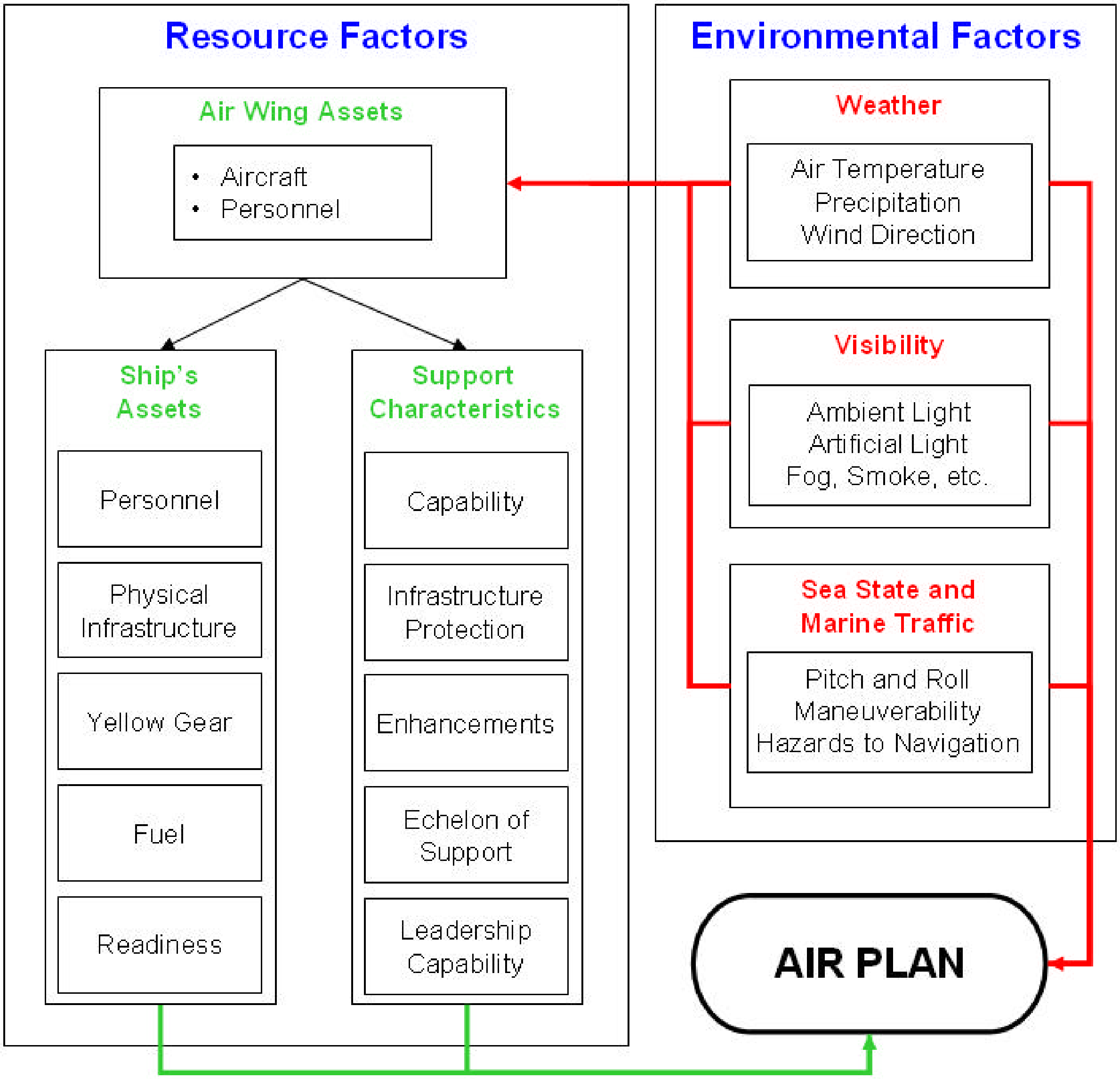


Figure 36. Aircraft Handling Influence Diagram

## I. SIMON'S MODEL FOR FLIGHT DECK PLANNING

When considering how best to approach problem solving in a complex operational environment, a traditional theory is that people made rational decisions first by searching for all the different possibilities, evaluating those possibilities and then deciding which alternative best solved the problem or filled the need.

Herbert A. Simon, the 1978 Nobel Laureate in Economics did extensive research in how people make decisions. His bounded rationality model supposition was that people made limited rational decisions by searching some possibilities, evaluating one, and deciding upon the one sufficient enough to solve the problem or fill the need.

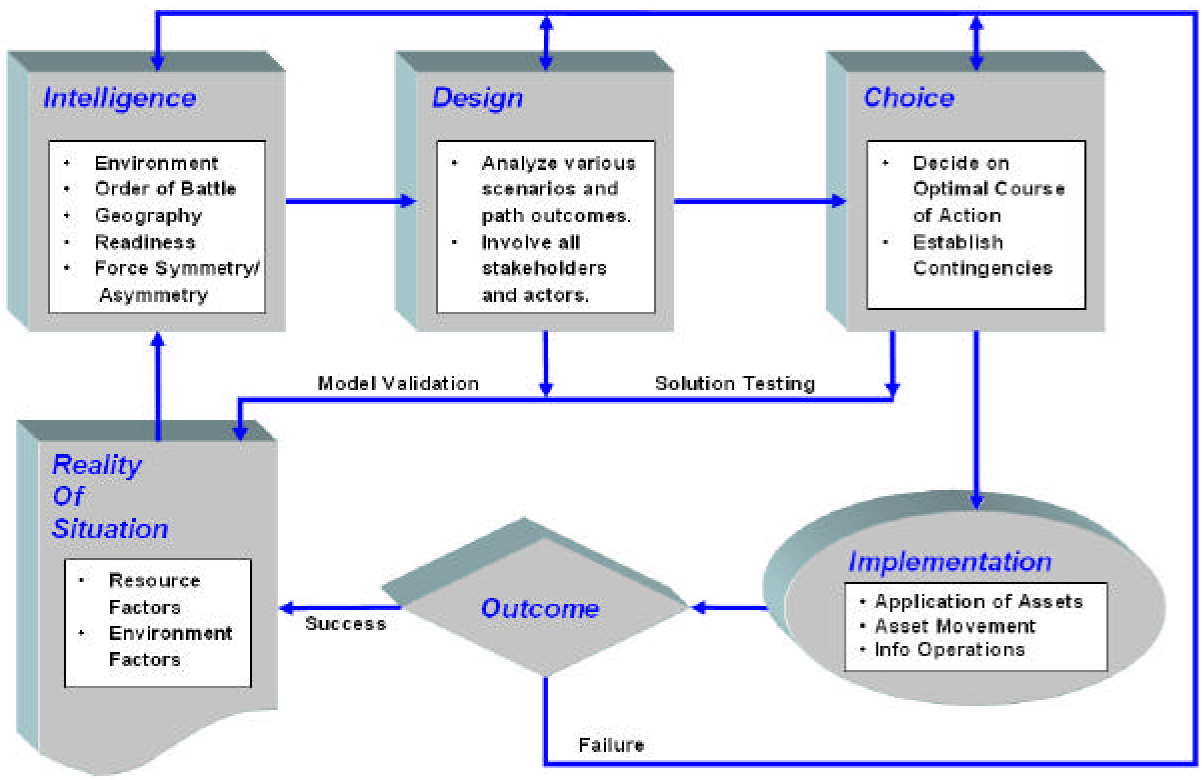


Figure 37. Simon’s Model Applied to Flight Deck Support

When developing a decision support system, Simon’s Model process becomes more realistic because it takes less time, yields an acceptable choice and cost significantly less in terms of time and resources.

Simon’s Model can also be readily used to illustrate the cyclical nature of Flight Deck Operations Support. As shown in Figure 37 above, the model quickly demonstrates the need for contingency plans and flexible structuring. In this way the

dynamics of the factors included in the Influence Diagram can be quickly considered and accounted for.

The strength of this model is the process. All factors are listed. The problem is identified and a criterion for the solution set is developed. Alternatives are listed and evaluated so the decision maker can pick the best alternative.

This process guarantees the best solution possible for the information given at a specific time. If something changes, the system can rapidly determine the next best alternative based on the change. According to Dr. Simon[48]:

> Expert systems are generally constructed in close consultation with the people who are experts in the task domain. Using standard techniques of observation and interrogation, the heuristics that the human expert uses, implicitly and often unconsciously, to perform the task are gradually educed, made explicit, and incorporated in program structures. Although a great deal has been learned about how to do this, improving techniques for designing expert systems is an important current direction of research. It is especially important because expert systems, once built, cannot remain static but must be modifiable to incorporate new knowledge as it becomes available.

Other issues to consider when evaluating a decision support model include:

- Not all factors or parameters are listed
- Wrong problem identified
- Criteria is politically motivated
- Incorrect evaluation of alternatives
- Shallow implementation
- Failure to recheck parameters
- Lack of aggressive implementation

48 Decision Making and Problem Solving, Herbert A. Simon et al., Research Briefings 1986: Report of the Research Briefing Panel on Decision Making and Problem Solving © 1986, National Academy of Sciences.

The strength of Simon's Model is that it is modifiable. The factors and parameters listed in Figure 37 are not inclusive nor take into consideration how the environment will change when new technology is adopted.

## J. ADAPTIVE PLANNING

Organizational structures will impact the effectiveness of an organization, but the environment, the mission, and available personnel and material will directly influence each possible structure. The basic structures are illustrated in Figure 38.

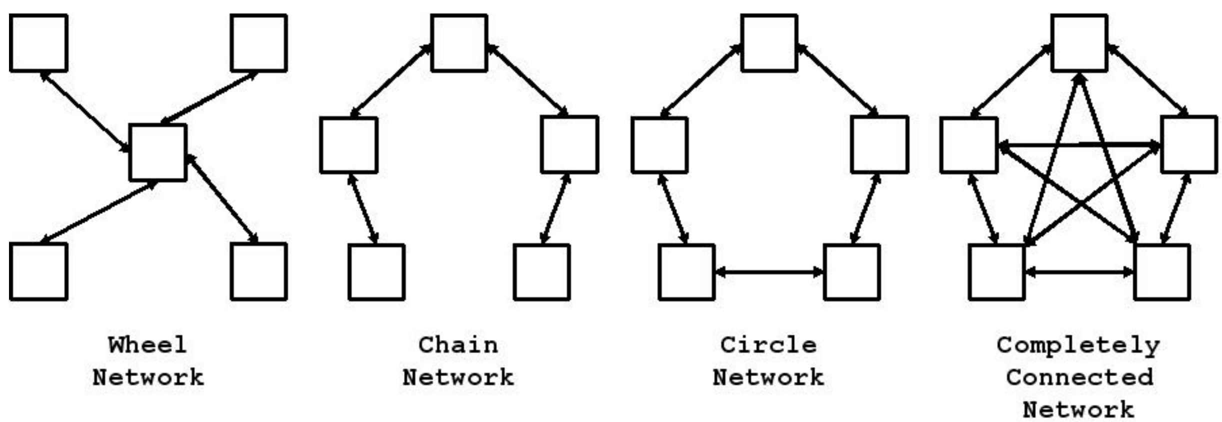


Figure 38. Basic Communication Network Structures[49]

The three basic Multi-participant Decision Maker (MDM) structures as suggested by C.W. Holsapple in 1991 are shown in Figure 39. George Marakas, author of "Decision Support Systems in the 21st Century" defines MDM as:

> Multi-participant decision-making is an activity conducted by a collective entity composed of two or more individuals and characterized in terms of both the properties of the collective entity and of its

[49] Adapted from *"Decision Support Systems in the 21st Century"*, George M. Marakas, Prentice Hall, 1999

individual members.[50]

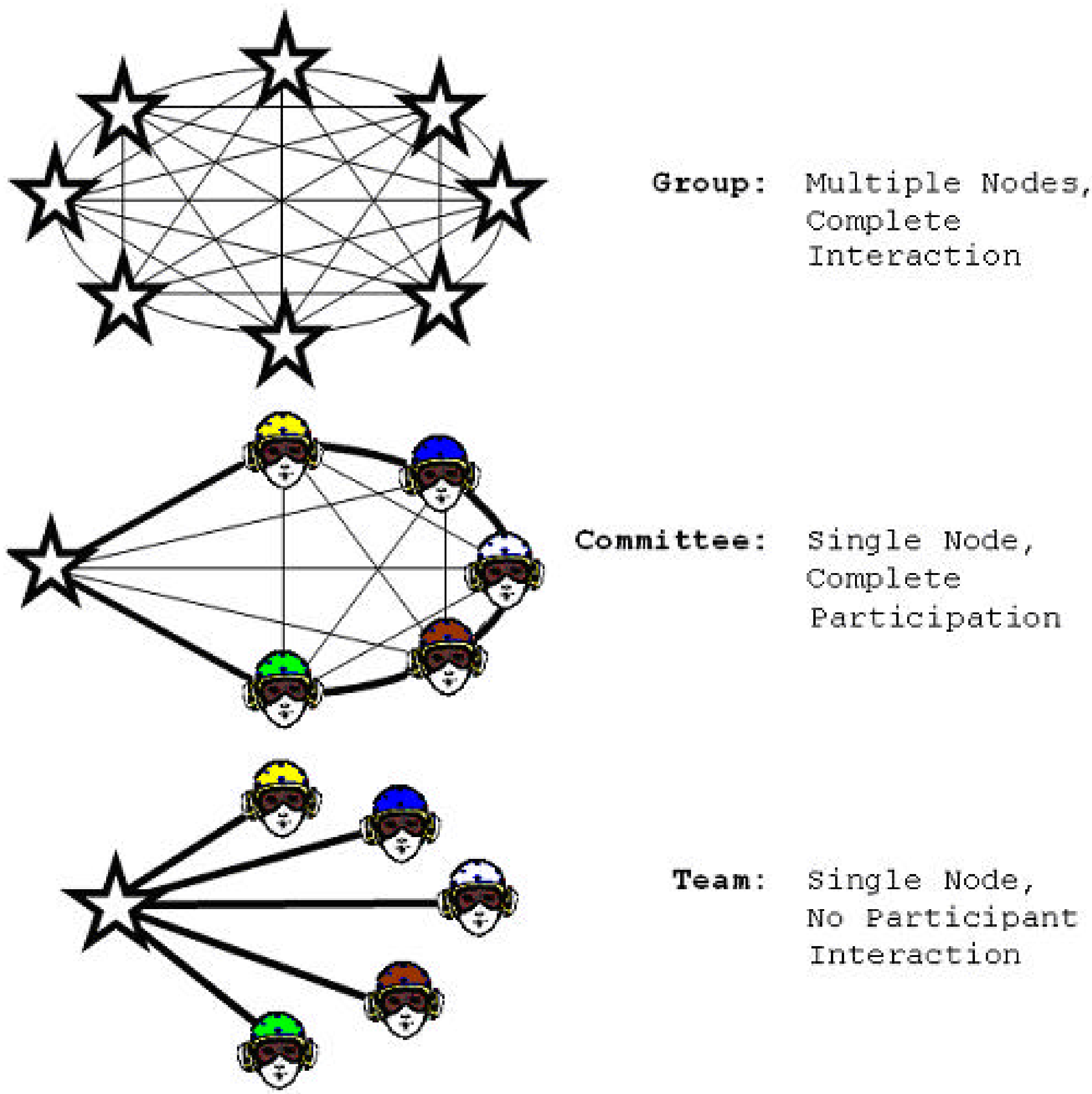


Figure 39. Basic MDM Structures[51]

Initial direction for aircraft handling will come from the ACHO in Flight Deck Control, but the individual on the deck will often observe the changes in the environment that will affect the overall plan. Therefore, the most efficient organizational

50 Ibid

51 Ibid

structure for Flight Deck Planning Operations, in most cases, will be the committee structure as illustrated in Figure 40.

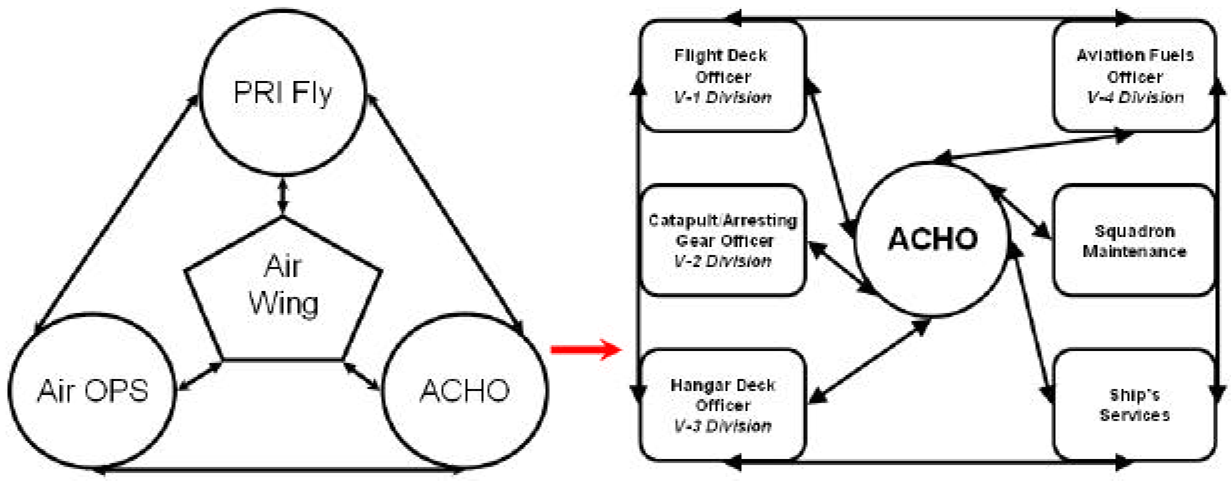


Figure 40. Flight Deck Planning Structure

This structure begins at the highest level in the chain of command, but will be adjusted according to the leadership preferences of the individual actors or centers as appropriate.

The actual interaction between the actors and centers will likely mirror the flow of information depicted in the influence diagram and Simon’s model.

## K. LAYERED DECISION TABLES FOR FDIP

The first step in defining parameters and criteria for evaluating collaborative tools for a complex organization is to identify a representative, but finite group of interdependent tasks and then map a logical flow of the associated information throughout the complex organization.

This process is tedious, but valuable in understanding some of the unique and dynamic information requirements. As shown in

Figure 41, the initial flow of information for flight deck operations can be modeled and analyzed.

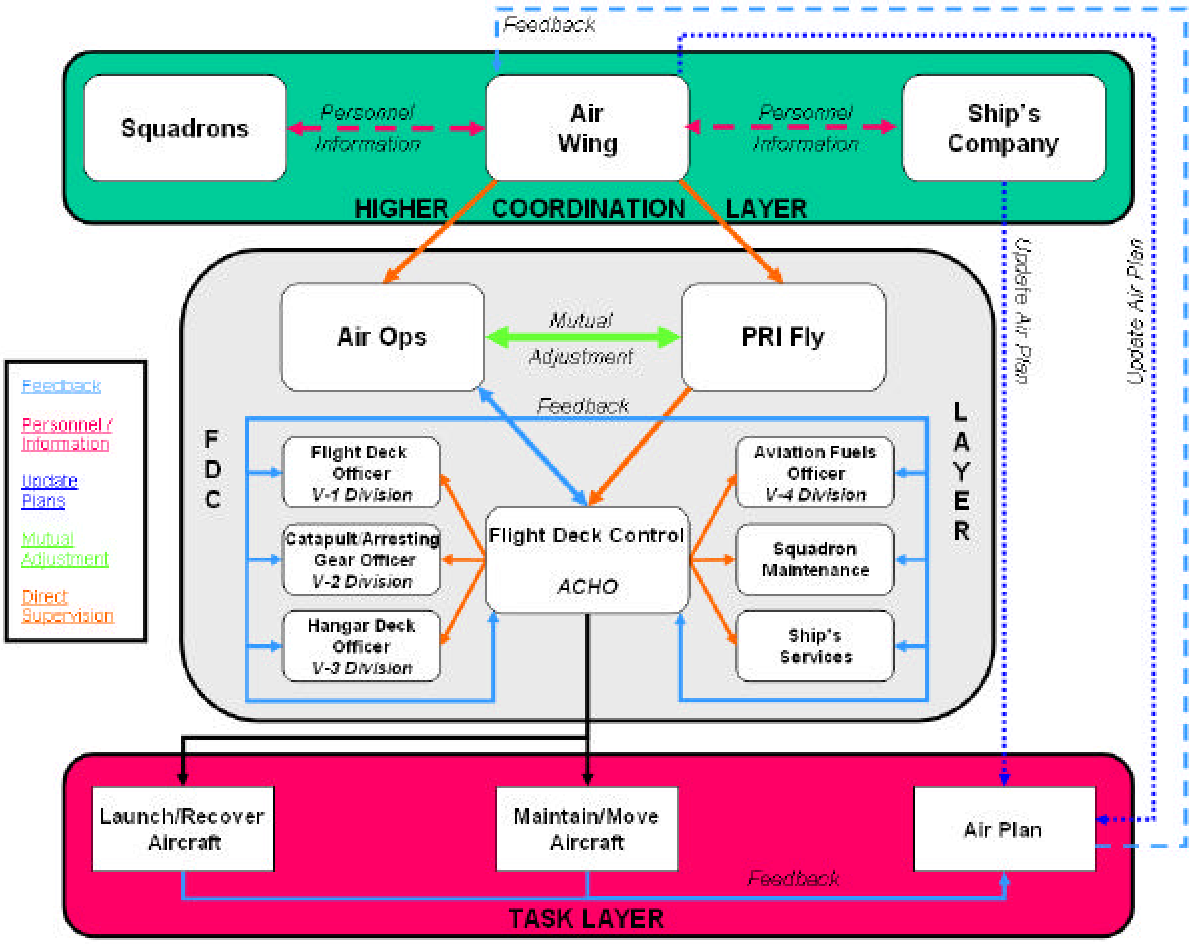


Figure 41. Layered Decision Tables

Appropriate decision tables can be established and populated based on standard operating procedures and lessons learned in previous operations. Once the decision tables are populated, the collaborative tools should streamline the decision process by “volunteering” information and prompting appropriate responses from users throughout the organization.

## L. THE HIGHER COORDINATION LAYER

Conceptually, the Higher Coordination Layer (HCL), as shown in Figure 42, is made up of a broadly dispersed network of area and subject matter experts from Ship's Company, from individual Squadrons, or from the Air Wing.

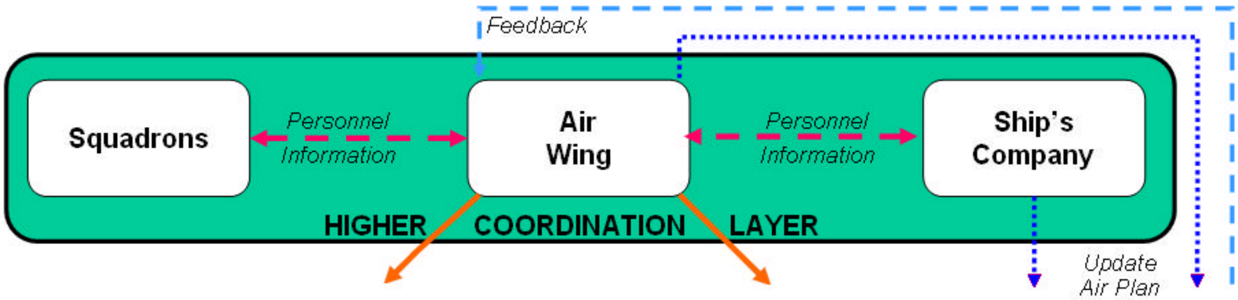


Figure 42. Higher Coordination Layer for FDIP

The HCL is connected primarily through face-to-face interaction and email, and the group would combine for regularly scheduled training. The subject matter experts provide direct liaison between the Air Wing and their parent activities.

In the HCL, a distributed social cognition (or heightened awareness of interdependency between organizational elements) must exist for the Air Wing to be successful and accomplish its goal. The overall goal in this layer is to integrate real-time situational awareness. All three entities must provide real-time collaborative operations and capability that will support planning, mission execution, monitoring, and rapid re-planning in the operational environment. Therefore, a strong foundation of unity of command and decisive real-time situational adaptation must exist.

## M. THE FLIGHT DECK CONTROL LAYER

The Flight Deck Control (FDC) layer defines the basic roles of all of the actors and their coordination roles and relationships as illustrated in Figure 43.

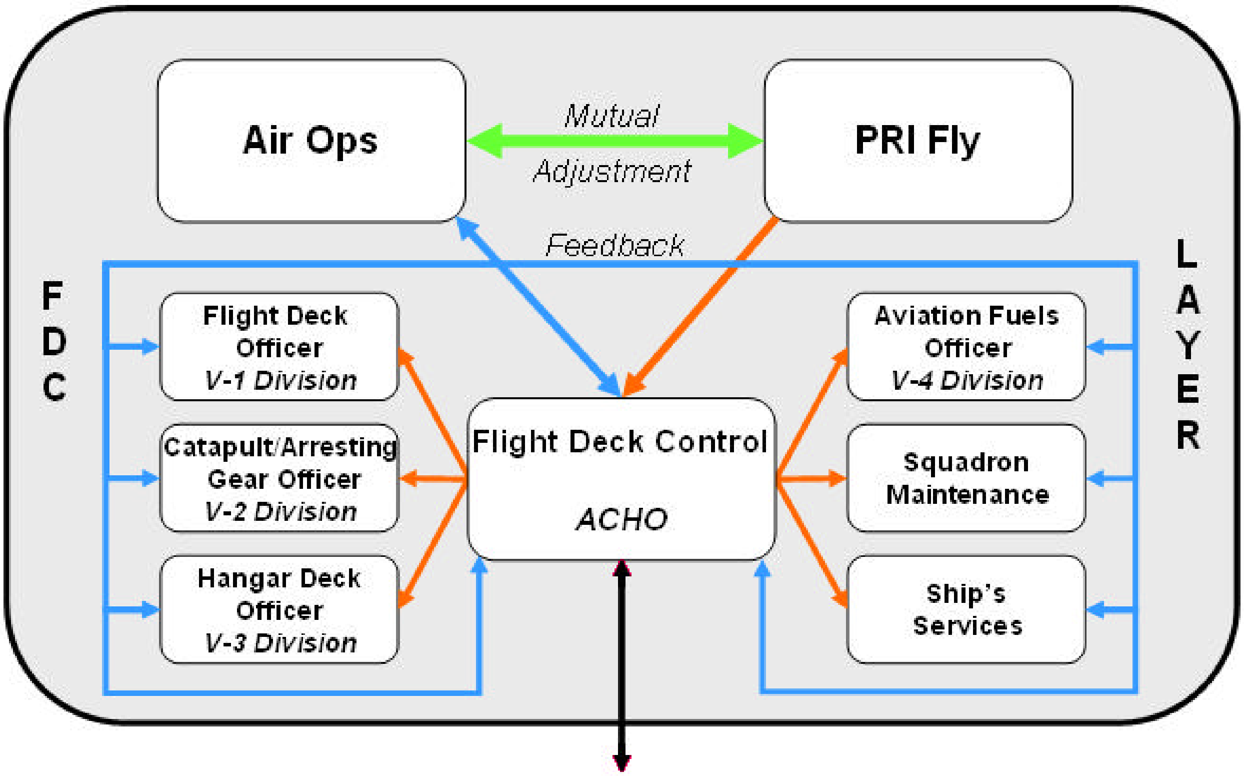


Figure 43. FDC Layer

The Air Ops, Air Boss, and ACHO form a team with the goal of transforming an operational requirement into a prioritized logistical task. This is accomplished through mutual assurance relationships.

The Air Operations Officer role is to ensure Flight Deck Control is responding to the operational commitments with the correct priority emphasis. The ACHO then inputs the task into the requirement node via the Flight Deck Control where it is input into a requirement database with the proper priority.

The relationship between the ACHO and Flight Deck Control is by direct supervision with the end goal of transforming the relationship into a mechanized bureaucracy. This mechanized bureaucracy is achieved through establishing and following Standard Operating Procedures (SOPs) and specific communication up and down the chain of command. Flight Deck Control delegates work to the appropriate service centers either sequentially or in parallel depending on the nature of the task at hand. Most tasks will require more than one center to contribute to an effective end. Table 4 below features examples of actors and associated sets of tasks. Therefore, even at this layer, there will be mutual adjustment or organizational compromise and what can best be characterized as a low level adhocracy. A low level Adhocracy combines elements of pure administration and simple bureaucracy. The outcome is a learned behavior to minimize delays in resolving issues between centers or actors.

| **FDC ACTORS and SERVICE CENTERS** | **TASKS** |
|---|---|
| Air Ops | • Operational Point of Contact for Higher Layer<br>• Coordinate Operational Requirements<br>• Liaison with Air Boss<br>• Liaison with ACHO to check status<br>• Adjust operational timelines as supported by Flight Deck Control |
| Air Boss | • Operational Point of Contact for Higher Layer<br>• Coordinate Operational Requirements<br>• Liaison with Air Ops<br>• Liaison with ACHO to check status<br>• Adjust operational timelines as supported by Flight Deck Control |
| Aircraft Handling Officer (ACHO) | • Point of Contact for Higher Headquarters |

| | |
|---|---|
| | • Coordinate Flight Deck Service Centers to support Operational Requirements<br>• Liaison with Operations Officer<br>• Directs the Logistics Center |
| Flight Deck Support Centers<br>• Flight Deck Officer<br>• Catapult/Arresting Gear Officer<br>• Hangar Deck Officer<br>• Aviation Fuels Officer<br>• Squadron Maintenance Officers<br>• Ship's Services | • Coordinates Support Tasks to meet Operational Requirements.<br>• Centers coordinate with each other and with Flight Deck Control<br>• ACHO can receive feedback from Flight Deck Control or from any of the Service Centers as appropriate |

Table 4. Actors and Tasks

Flight Deck Control coordinates the service centers by direct supervision to meet the requisite variety of the task and its corresponding dynamic environment. The service centers work with one another in a mutual assurance-supporting role where they are forced to coordinate on their own terms. When conflicts arise, it will be de-conflicted by direct supervision from either Flight Deck Control or the ACHO.

In the FDC layer a continuous process of OODA cycles exist. This process can be analyzed in terms of planning and execution. As missions occur the process follows a logical step of coordination through Flight Deck Control with all its components. This OODA process represents an organization exhibiting distributed social cognition as an emergent behavior.

## N. THE TASK LAYER

The FDC task layer, as illustrated in Figure 44, will function to perform various tasks or solve problems. Therefore,

the “Problem Focused” process will ultimately exist throughout all layers of the network. Also, as seen in all layers, multiple simultaneous processes will exist. Each process will address a specific task, but there will be circumstances where more than one process will compliment another to solve a specific problem.

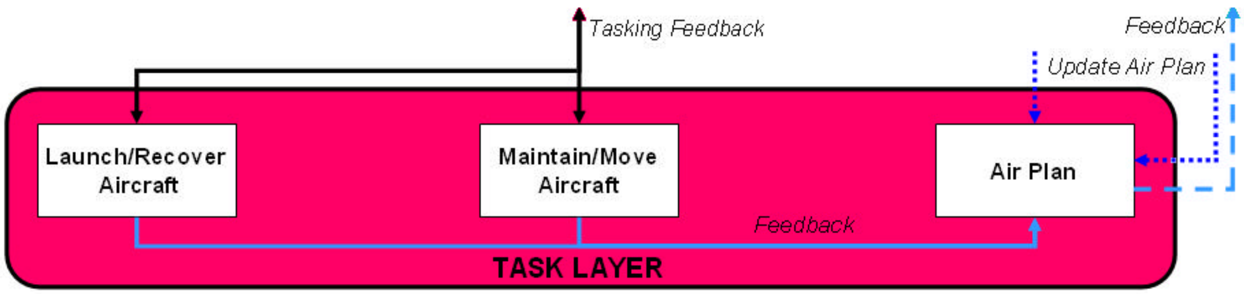


Figure 44. The Task Layer

Intra and inter-coordination will be realized by the social cognition of the organization as a whole. Coordination is achieved through mutual adjustment and direct supervision (as described in the FDC Layer section above).

This is the primary organizational structure in this dynamic scenario. Social cognition of the organization will be fully realized in the Decision Support System, but only after the decision tables are populated.

## O. FDC COLLABORATIVE TOOL AND AGENT TEST BED

The following tools or tool developments appear well suited for continued evaluation of Flight Deck Interactive Planning concept:

- ORBIT (workspace environment)
- Collaborative Virtual Workspace (CVW)
- COMPASS Collaborative Package
- Info Work Space (IWS) (workspace environment)
- ODYSSEY (workspace environment)
- GENOA Segments (web tools)
- Adaptive Course of Action (ACOA) tools
- Advanced Concept Technology Demonstration (ACTD) tools
- MSIAC tool package
- Course of Action Display and Evaluation Tool (CADET)
- FOX Genetic Algorithm

The Naval Postgraduate School (NPS) has a regular student base of over twelve hundred military officers. The student body includes international officers from both NATO and coalition countries.

From an operational perspective, there is a wealth of knowledge and experience at NPS that would facilitate meaningful evaluation of collaborative tools and intelligent agents to support Flight Deck Interactive Planning (FDIP) and Flight Deck Command and Control ($FDC^2$) initiatives.

## P. AGENT COMPONENTS FOR FLIGHT DECK CONTROL

The Intelligent Agent (IA) architecture should be expanded to facilitate more effective action/reaction times to changing circumstances impacting an operational mission.

The goal is to keep the decision makers informed of “real time” critical information that would directly impact the mission. Looking at the Observation, Orientation, Decision, and Action (OODA) loop model, effective planning and timely updates would reduce “observe” and “orient” times and allow the war fighter to decide and act faster than the adversary. The quicker OODA loop would ultimately be more responsive and keep the enemy off balance or “paralyze” him to the point of being ineffective.

For example, once the primary planning cell assessed a crisis and developed the overall plan, several logical Courses of Action (COA) could be identified.

Intelligent Agents could facilitate extensive direction, collaboration, and coordination before and throughout an entire mission. Additionally, they could translate a proposed COA into a statement of requirements and provide tailored packages depending on operational requirements and the operational environment.

Scenario driven solutions would enable projected aircraft spotting and re-spotting requirements. This leveraged knowledge would allow Flight Deck support personnel to make real-time analysis of present and future necessities.

Central to all other capabilities is the ability to collaboratively translate plans of aircraft movement into plans of support and then to responsively assess the strengths and weaknesses of the resulting plans. This translation and assessment capability contributes not only to reduce operational risk, but also to preserve operational options for the Air Wing.

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# VII. RECOMMENDATIONS

## A. INTRODUCTION

Our recommendations are based on the research we have conducted and our experiences while interacting with various agencies and companies during our data collection. One of the requested outputs of this thesis is a recommendation on how, from a business perspective, this project would proceed, and which entities (companies, DOD activities, etc.) would logical continue this work.

We have attempted to display the recommendations as requirements for a fielded system. As such, many of the requirements could be considered independently or deleted from the system without completely disabling the system or reducing the value added it would have for the fleet. However, some of these requirements will have to be integrated for the system to function correctly. Accordingly, we will annotate items of importance as “system critical” in an attempt to safeguard those items from future removal or uninformed modification.

Depending on the time it takes to endorse and incorporate our findings into a true requirements document and then field the system, newer technology will likely be commercially available. Therefore, it is our opinion that the system be designed with change in mind. The system should be designed to rapidly shift to faster hardware or operating systems to enhance system performance.

## B. REASONS FOR ADOPTING CHANGE

The current system as described in previous chapters is effective, but is not at all efficient. The most compelling

reason for this organization to embrace change would be to increase the efficiency of updating and disseminating operational information used by the various departments that require it. This vision compliments the publicized operational goals of the newest class of U.S. aircraft carriers. Specifically, CVNX charter requires a 20% greater sortie rate than the current Nimitz Class carrier with the *same* number of personnel, aircraft, and deck space.

Our contention is that the only way this goal can be realized is to leverage every technological advantage possible.

## C. RECOMMENDED CHANGES

A “system of systems” requires a streamlined design that will integrate all the latest software technology and database advancements. The current system is a case study in legacy applications that are all unique solutions for individual problems. Apparently little thought was given to data visibility to other applications when many of these systems were developed; hence interoperability was not a significant consideration when these “stovepipe” systems were designed. Further, redesigning these legacy systems will be time consuming and costly.

As discussed in the Agents chapter in this thesis, it would be possible to create an interface layer that would theoretically facilitate legacy system interoperability. Intelligent agents could be used to create the linkage between the disparate systems. However, this approach has significant flaws. First, many of the systems that would be linked by an agent layer are funded by different sources and are essentially treated as stand-alone systems. Each system has a life of its

own and it cannot be expected that each program will routinely consider other interfacing systems. If a system or program were discontinued, all secondary users would be impacted. Functionality and information would be lost until a “workaround” was determined or until a new system was plugged in to replace the previous system.

Furthermore, designing intelligent agents that would permit interoperability would require all of the individual systems interfaced to remain stable. If one of those systems were upgraded, then the unifying agent’s layer would have to be tested and possibly reprogrammed to sustain functionality and connectivity. It is clear that the agents themselves will inherently be robust, but any system modifications will undoubtedly require a planned re-certification to verify that changes had no adverse effect on other mission critical systems.

There is also the issue of ownership. Who will be responsible for the agent management and evaluation? Individual Program Managers from the various systems will be reluctant to adopt these costs, as the agent layer is not part of their system. It would initially be considered beyond the scope of their project to evaluate the effect of changes in their software or hardware on other systems.

Yet another issue is a question of performance and the ability of these legacy systems to shift to more efficient technology. For example, 2 GHz chips and GIGABIT Ethernet are commercially available. How many years will pass before this technology is integrated into military systems?

The ADMACS system is running on a proprietary Hewlett Packard (HP) system that has not been manufactured in over five years. HP no longer supports it. NAVAIR is apparently

compensating by acquiring legacy HP Systems from other governmental entities or from Defense and Reutilization & Marketing Service as components are discarded.

Engineers at Northrop Grumman's Newport News Ship Yard suggest that the data management system be overhauled first. We agree. Deliberately establishing a foundation database capable of handling a myriad of system and sensor information is logical. Any use of automated sensors for aircraft position and orientation information is useless without a system robust enough to appropriately and efficiently handle the large volume of data.

In theory, the ADMACS system has this architecture. It is our observation, however, that ADMACS is largely dependant on fixed hardware and legacy systems run on proprietary and inflexible software. The hardware is not "state of the art", and therefore, the potential performance possible with newer technology will not be easily realized. This could have significant ramifications when considering the addition of multiple complex integrated sensors. It is our opinion that NAVAIR revisit current ADMACS efforts and purposefully redesign the entire system.

Initially, we would recommend the two primary Type Commanders (TYCOMS) (COMNAVAIRPAC and COMNAVAIRLANT) facilitate comprehensive requirements modeling for aircraft handling to definitively identify all of the functional requirements that a ship-wide system would have. Again, many of these data requirements are listed in the ADMACS Integration List (Appendix A). The drawback to this initial list is that it comes directly from the ADMACS program.

This approach enforces the premise that the “Fleet” determines system requirements.

## D. IDEAL SYSTEM ATTRIBUTES

**One Database** - The ideal system will have a single database with segregated data fields so that specific users will have the ability to modify only the fields that they have cognizance over.

For example, the squadron could only change information regarding a squadrons’ aircraft, such as configuration and “up” or “down” status. Numerous users including V-4 or the squadron who owns the aircraft, however, could modify an aircraft’s fuel status. In this case, the squadron could input the initial fuel quantity, but the Fuels Division could update the refueling (or de-fueling) status.

**Develop Accurate Requirements** - The ADMACS team and others, such as Northrop-Grumman have utilized process modeling to assist in developing the system requirements. This is desirable since there are many variables with multiple dependencies in the daily operation of the flight deck. It is imperative that the modeling is accurate in all of the steps that are involved in regular and special evolutions.

NAVAIR and a third party (one independent of the acquisition process and one without to prospective contractors) will be crucial for the modeling flight deck operations.

The Modeling, Virtual Environments and Simulation (MOVES) Institute at the Naval Postgraduate School (NPS) is a logical candidate for this work. Note that the NPS is able to compete for SBIR contract work from other Navy (and other government) activities.

**Establish Data Ownership** - Once the processes are accurately modeled, all of the required data fields for the database can be established. Specific ownership can then be applied to each data field. It stands to reason that there will be some debate over who should have ownership of some fields, but the TYCOMs will be the logical players to mediate such discussions.

**Suggest Courses of Action** - Input from interviewees made it abundantly clear that a system that proposes solutions and alternatives is desirable – one that mandates an action is not acceptable. We understand and agree with these assertions. This system is envisioned to assist operators, not replace them. We have a deep appreciation for the abilities of the Handlers who currently do their jobs with a minimal amount of technology. But, we believe that a new system will aid Handlers by giving them more accurate and timely information allowing the operators to make the best decisions.

The added benefits that we envision are that every other air operations activity aboard the ship will be able to see what is going on, without having to contact FDC or the ACHO. An additional benefit is that the system can be used to train other personnel to be handlers. Both the Handler and the trainee can "what-if" the system to death, making full use of a built in "scenario" capability. The ramifications of this capability cannot be overemphasized. For instance, if a part is on order for one of the catapults, the Handler could run a scenario illustrating how not having that catapult will effects operations. The impact of that part not getting to the ship on time can be easily documented using a cause and effect approach.

This scenario can also be used to show the cumulative effect on the next days Air Plan.

**Flexible Interface Capability** - Other input stressed the need to allow the users to customize the interface to give them as much or as little data as they require for their job or for their leadership style. It is reasonable to assume that the display options could be programmed for this type of functionality. For example, the Fuels guys have less need for details about ordnance requirements for a particular aircraft unless the ordnance impacts if they can fuel or de-fuel an aircraft. Likewise, the Handler may want to see just the “comers” or just the aircraft that are up for the next launch. This level of customization should be considered a priority to the system design.

**Accuracy and Latency** – The current EATS is accurate to within a few feet. This may prove to be accurate enough in the short-term as it is certainly more accurate than the current manual system. It stands to reason, however, that more accuracy will provide more efficiency. If the handler is able to visualize the aircraft stacked in the Bow Rows to within an inch, he may be able to park an additional aircraft on the bow that he might have attempted otherwise. The sensors should be able to deliver accuracy to within 1 to 2 inches on the approximate 100 meter by 300-meter flight deck.

Obviously, the system should have as little latency as possible. Again, the experience with EATS is that refresh rates much less than that used for motion pictures are sufficient. This assumes targets as large as aircraft and speeds less than 15 MPH. If future capabilities of the system require tracking of humans or even human hand motions, refresh rates should be

increased. Ideally, the display should be able to display the movement of aircraft as a smooth, non-hesitating motion. This flow will be perceived as a measure of accuracy. For example, if the aircraft is displayed in a jerky way, the system will be perceived as less accurate.

**Effective use of Intelligent Agents** - Latency and accuracy both are dependant on the sensors used. The number of and integration of sensors will play a large factor on the bandwidth and processing power required to accurately display the objects. Obviously, if the number of sensors increases, sensor integration will be a bigger challenge.

Sensor integration is an appropriate place to use Agents. Discussions with Lockheed's ATL left us with the impression that they could address this sensor integration problem by appropriately coding agents to correlate track information seen by multiple sensors such that the display would reveal a more accurate and complete depiction of the situation on the deck even when some of the sensors might be obscured. Additionally, agents would be able to predict motion when a sensor is temporarily "blinded" by an obstruction. Agents would be able to alert the human operator if a track lost its identification information. The operator would be prompted to re-identify the target for the system.

**System Reliability** – Due to the interdependency built into a system such as this, too many mission critical processes will be affected in the event of an unscheduled system failure. Adequate system redundancy and critical path analysis will be imperative to ensure that the system is either up or functional even in a degraded state while technicians correct whatever failure occurred.

The level of reliability can be scientifically established and appropriate hardware and software redundancy designed into the system. As shown in Figure 45, reliability can be defined in minutes of system downtime during a specific period.

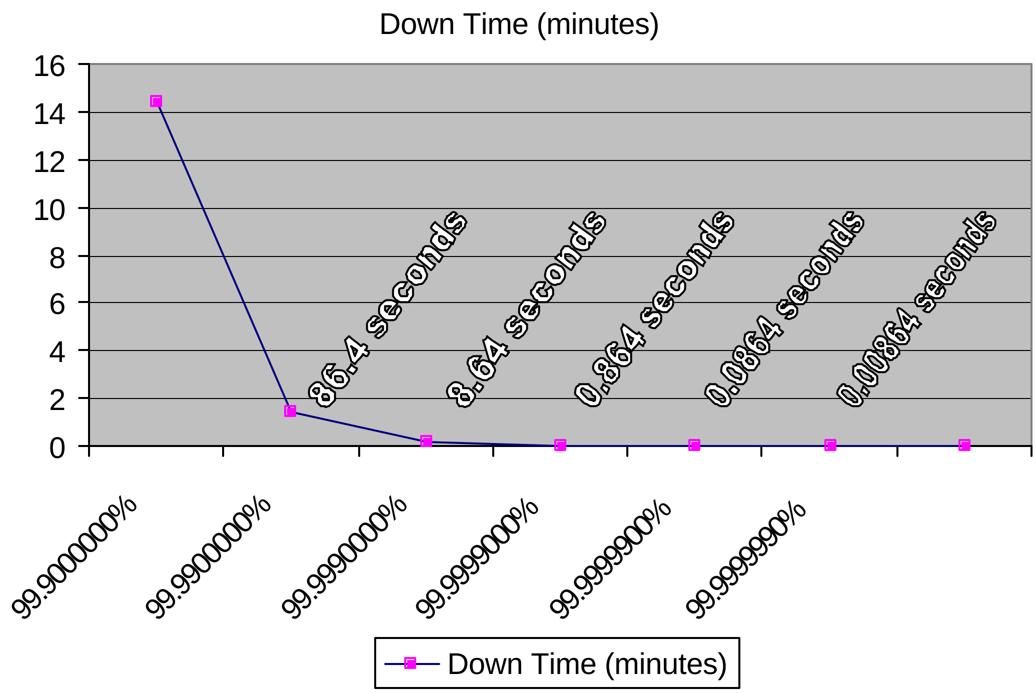


Figure 45. Down Time

In general, if the system required 99.99% reliability, the system would be unavailable a total of 86.4 seconds during that reporting period. Considering safety will be directly impacted by system down time, reliability should be increased appropriately.

The current emphasis in Department of Defense and in particular Department of the Navy is the use of Microsoft based products in support of Information Technology for the 21st Century (IT-21) and Navy Marine Corps Internet (NMCI) initiatives. As a result of this emphasis, many of the enlisted technicians are trained specifically as Microsoft technicians in

order to be able to address the issues that they will most likely encounter.

Our intention is not to dictate a particular software package for use as the operating system, the database, or any of the application interfaces. It will be incumbent upon the actual systems designers and the Project Manager to make a considered choice as to which software will provide the balance between reliability and serviceability. It has been our experience that proprietary software or even non-Navy standard software can be problematic when used in an environment, such as a ship at sea, which does not readily allow service calls from the vendor. The danger of using a Linux or UNIX operating system is the added requirement for specially trained technicians to service the system when the need arises. It is not reasonable to assume that this system, if written on non-Navy standard software, would be large enough for the Radioman (Data Processing) “A” school to shift its curriculum to focus more on non-Microsoft products.

A strategy can also be determined to anticipate system recovery upon a failure. For example, data could be cached in the functional work center that “owns” the data.

In order to allow for graceful degradation and systematic recovery of data after a system failure, the data “owner” could have local data storage of the data fields under his cognizance. These local stores could then regularly synchronize with the main database when connectivity is reestablished. This provides for continued local functioning even when partial or entire system disruption occurs, and it allows for the system to reestablish the most current information to all users, as the different functional areas come back on-line.

Since many users and applications depend on data from other functional work centers, their data will also need to be cached locally in the event of a system malfunction or shipboard casualty. The only practical difference between the two situations stated above is that the second type of user will not be able to update or change the data that he does not usually have the ability to change.

## E. POSSIBLE PARTICIPANTS

The current ADMACS engineers and program managers from Lakehurst should be involved in this effort. Our work on this thesis has allowed us to interface with numerous software and hardware vendors, as well as DoD contractors who have a long history of doing business with the DoD and in particular with the Navy.

We do not necessarily believe that Lakehurst should be the lead in this new system development. There is a developmental history that exists with the current system, ADMACS, and considering the significant investment in that program, any lessons learned should be used. But it is evident that system design should be approached from outside the established organization to avoid the pressure to maintain the status quo.[52]

Northrop-Grumman has developed and presented an impressive prototype. Considering past performance in other successful defense project, we feel that they are a logical contractor to approach in developing this system. More importantly, they are the prime contractor on the CVNX project.

[52] We were informed that NAVAIR has spent over $74 Million on the current system. It is not clear if this includes pre-payment to establish the system on all current Carriers, but to date it is not deployed on all.

While it is obvious that this system will primarily serve the Air Wing and the Air Departments aboard a carrier, this system is still a *shipboard* system. It should be designed and developed as an integral part of the next-generation carrier. This again makes the Northrop-Grumman recommendation a logical one.

Informal discussions with other companies have made it clear that there is both industry knowledge and industry interest in a project like this.

One of the most recent responses we received from Raytheon[53] describes, in no uncertain terms, that they can provide the sensor portion of this system with current technology that they have developed for other DOD programs. This could be particularly beneficial in keeping the costs down by reusing DoD assets.

Pulnix Corporation, Develosoft, and the other companies mentioned in this thesis should also be considered.

## F. REVIEW OF EXISTING AND DEVELOPMENTAL SYSTEMS

The proposed ADMACS Block II Upgrade stated that system integrators would need to have a firm grasp of (a) what all of integrated systems contained, and (b) what ADMACS needed from each of those systems.

It is apparent that there is more than one way to effectively integrate systems, but we believe the first goal of the system integrator will be to avoid trying to maintain all the legacy systems (the status quo). The issues will always be

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[53] E-mailed proposal from Joseph R. Wood, Senior Principal Electronics Engineer, Raytheon Company, Projects Department, Electronic Systems Laboratory, P.O. Box 1201, Tewksbury, MA. 01876-0901

complex, but the biggest barrier to successful change in this system will not be technology, but organizational culture.

With this difficulty aside, we were able to ascertain that there are hundreds of data fields in fifteen or more systems that are identified for the ADMACS to use as data sources.

Appendix A details various input datum from the different systems. The appendix is primarily organizational and does not detail the specific data or data format to and from other systems. The output from an individual input system is less important at this point since, in our opinion, the correct thing to do is collect all of the data into one powerful database that will be able to "feed" any existing or subsequent system developed for future applications. In fact, we believe that once this database is developed, many of the legacy systems would quickly become obsolete.

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# VIII. CONCLUSIONS

The ability to make effective decisions with limited resources has never been more important. Approaching the Digital Ouija Board from integrated system architecture as shown in Figure 46 illustrates how complex it can be to provide meaningful information to the war fighter. The direct benefit of this visualization is that the elements can be addressed and appropriate technology adopted and integrated.

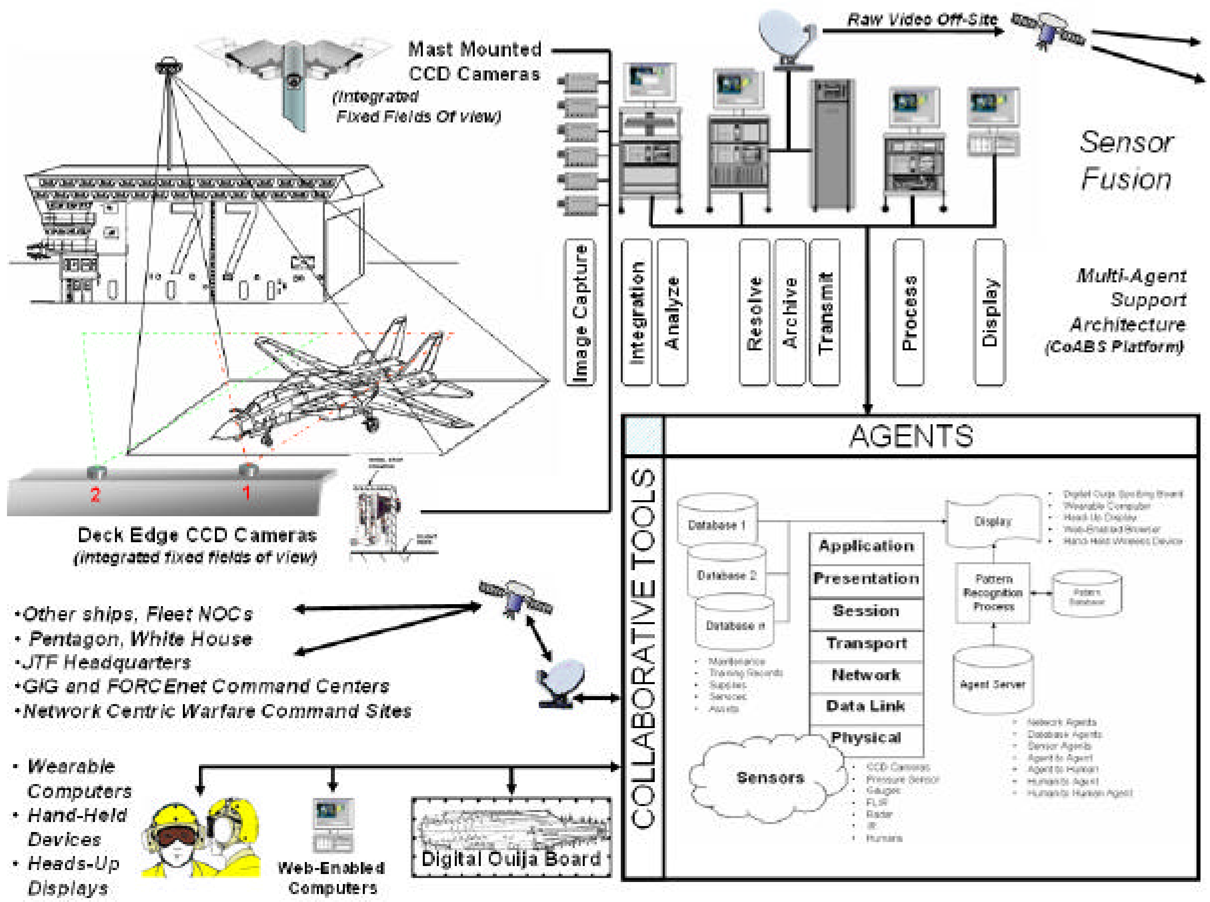


Figure 46. Integrated System Architecture[54]

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54 Computer Equipment graphics adapted from www.sensorsapplications.com, June 20, 2002

Emerging collaborative tools, intelligent agents, and “cutting edge” technology can be effectively and proactively integrated into all facets of flight deck planning and mission execution.

If the United States military strategically plans to continue to overwhelm enemies, advanced and flexible collaborative tools and intelligent agents will be of paramount importance.

Accurate “requirements modeling” will be necessary for subsequent research efforts to effectively identify the collaborative tools and intelligent agents to support “Rapid Decisive Operations” in projecting air power.

The current Aviation Data Management and Control System (ADMACS, described in Chapter III) system software is running on proprietary Hewlett Packard hardware that is no longer manufactured. Since a computer’s useful life is approximately three years, the system architecture should plan regular upgrades and embrace open standards that will make future interoperability less of a problem.

The sensor system that feeds the data management system should be platform independent. In a modular sense, today’s sensor will be replaced by something more effective tomorrow. The change should be transparent to the user because system functionality would be consistent. The CoABS multi-agent middleware recently developed by DARPA serves that goal.

The Peer-to-Peer (P2P) Limited Objective Experiment detailed in chapter four demonstrated how network management tools could be used to view a complex organization and monitor the flow of information.

The same tools should be used to design the information system that will support the Ouija board. This system can be virtually assembled and analyzed through simulations, then modified as necessary. More importantly, as the actual system is used in the operational environment, it can be monitored and managed as elements or nodes are added or removed from the network.

The ability to capture, archive, and analyze live network traffic will provide system engineer’s and managers the documentation to justify meaningful improvements to subsequent versions of the system.

In view of recent asynchronous terrorist attacks on the United States, the ability to rapidly identify a mission, identify required personnel and critical material will make the difference between ultimate mission success or mission failure.

The primary benefits of passive video capture, real time three-dimensional rendering and P2P communications on the flight deck or hangar bay is enhanced operational awareness. The infrastructure that facilitates this awareness will be the foundation for future advances in operational effectiveness. Approaching flight deck communication and operational command and control tasks from a network management perspective will allow the organization to use a broader range of tools to deliver operational success.

Collaborative tools and environments as well as dynamic intelligent agents will be integral to successfully moving against adversaries as they are revealed regardless of where they might be in the world.

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# APPENDIX A: ADMACS INTEGRATION LIST

| WORK CENTER (USER) | | | |
|---|---|---|---|
| IDENTIFICATION | LOCATION (CVN68 class) | SYSTEM / Application | LABEL (Data / Data Blocks) |
| ALL | | | System Status |
| ALL | | | Time |
| Air Operations | 03-170-0 | ISIS | Air Plan |
| Air Operations | 03-170-0 | ISIS | Airborne Tanker Status |
| Air Operations | 03-170-0 | ISIS | Alert Aircraft Status |
| Air Operations | 03-170-0 | ISIS | ASW Datum |
| Air Operations | 03-170-0 | ISIS | Bingo Fuels |
| Air Operations | 03-170-0 | ISIS | Charts / Maps |
| Air Operations | 03-170-0 | ISIS | Communication Plan |
| Air Operations | 03-170-0 | ISIS | Current Ship's Position |
| Air Operations | 03-170-0 | ISIS | Current Ship's Weather |
| Air Operations | 03-170-0 | ISIS | Daily Call Signs |
| Air Operations | 03-170-0 | ISIS | Divert Aircraft Status |
| Air Operations | 03-170-0 | ISIS | Divert Field Info |
| Air Operations | 03-170-0 | ISIS | Equip (Radar) Status |
| Air Operations | 03-170-0 | ISIS | Event Information |
| Air Operations | 03-170-0 | ISIS | Helo Status |
| Air Operations | 03-170-0 | ISIS | Pilot Qualifications/Grades |
| Air Operations | 03-170-0 | ISIS | Plane Guard Ship |
| Air Operations | 03-170-0 | ISIS | Recovery Video |
| Air Operations | 03-170-0 | ISIS | Ship's PIM |
| Air Operations | 03-170-0 | ISIS | Tanker/Helo Status (Deck) |
| Air Operations | 03-170-0 | MORIAH Wind | Wind Speed & Direction |
| AOCC | 1-74-2-Q | AWIMS | Bomb Farm Log |
| AOCC | 1-74-2-Q | AWIMS | Magazine Arrangement |
| AOCC | 1-74-2-Q | AWIMS | Master Magazine Temp Log |
| AOCC | 1-74-2-Q | AWIMS | Mission Load List |
| AOCC | 1-74-2-Q | AWIMS | On Load & Flow Sheet |
| AOCC | 1-74-2-Q | AWIMS | Status Board |
| AOCC | 1-74-2-Q | AWIMS | Weapons Inventory/Info |
| AOCC | 1-74-2-Q | ISIS | Air Plan |
| AOCC | 1-74-2-Q | ISIS | Event Information |
| Arresting Gear Officer | 04-230-S | ALRCS | Aircraft Bulletins |
| Arresting Gear Officer | 04-230-S | ALRCS | ALRE Status / Information |
| Arresting Gear Officer | 04-230-S | ISIS | Event Information |
| AUXCON | 08-159-0-C | MORIAH Wind | Wind Speed & Direction |
| BALLOON INFLATION RM | 01-255-3-Q | ISIS | Event Information |
| BALLOON INFLATION RM | 01-255-3-Q | MORIAH Wind | Wind Speed & Direction |
| BOMB ASSY MAG | 6-84-0-M | AWIMS | Status Board |
| BOMB ASSY MAG | 5-129-0-M | AWIMS | Status Board |
| CAG Ops | 03-138-2 | AWIMS | Mission Load List |
| CAG Ops | 03-138-2 | AWIMS | Weapons Board |

| WORK CENTER (USER) | | | |
| --- | --- | --- | --- |
| IDENTIFICATION | LOCATION (CVN68 class) | SYSTEM / Application | LABEL (Data / Data Blocks) |
| CAG Ops | 03-138-2 | ISIS | Airborne tanker status |
| CAG Ops | 03-138-2 | ISIS | Aircraft Status (Deck) |
| CAG Ops | 03-138-2 | ISIS | Aircraft Weight |
| CAG Ops | 03-138-2 | ISIS | Alert Aircraft Status |
| CAG Ops | 03-138-2 | ISIS | Bingo Fuels |
| CAG Ops | 03-138-2 | ISIS | Charts / Maps |
| CAG Ops | 03-138-2 | ISIS | Communication Plan |
| CAG Ops | 03-138-2 | ISIS | Current Ship's Weather |
| CAG Ops | 03-138-2 | ISIS | Divert Aircraft Status |
| CAG Ops | 03-138-2 | ISIS | Divert Field Infomation |
| CAG Ops | 03-138-2 | ISIS | Event Information |
| CAG Ops | 03-138-2 | ISIS | Event Information |
| CAG Ops | 03-138-2 | ISIS | Pilot Qualifications/Grades |
| CAG Ops | 03-138-2 | ISIS | Recovery Video |
| CAG Ops | 03-138-2 | ISIS | Ship's PIM |
| CATCC | 03-170-1 | ISIS | Air Plan |
| CATCC | 03-170-1 | ISIS | Airborne tanker status |
| CATCC | 03-170-1 | ISIS | Alert Aircraft Status |
| CATCC | 03-170-1 | ISIS | Bingo Fuels |
| CATCC | 03-170-1 | ISIS | Charts / Maps |
| CATCC | 03-170-1 | ISIS | Communication Plan |
| CATCC | 03-170-1 | ISIS | Current Ship's position |
| CATCC | 03-170-1 | ISIS | Current Ship's Weather |
| CATCC | 03-170-1 | ISIS | Daily Call Signs |
| CATCC | 03-170-1 | ISIS | Divert Aircraft Status |
| CATCC | 03-170-1 | ISIS | Divert Field Info |
| CATCC | 03-170-1 | ISIS | Equip (Radar) status |
| CATCC | 03-170-1 | ISIS | Event Information |
| CATCC | 03-170-1 | ISIS | Event Information |
| CATCC | 03-170-1 | ISIS | Pilot Qualifications/Grades |
| CATCC | 03-170-1 | ISIS | Recovery Video |
| CATCC | 03-170-1 | ISIS | Ship's PIM |
| CATCC | 03-170-1 | ISIS | SPN-46 info |
| CATCC | 03-170-1 | ISIS | Tanker/Helo Status (Deck) |
| CATCC | 03-170-1 | SPN-46 | SPN-46 info |
| CATCC | 03-170-1-Q | MORIAH Wind | Wind Speed & Direction |
| CATOFF1EMERGENCY CONTROL STATION | 04-149-2(P) | ALRCS | Launch Info |
| CATOFF1EMERGENCY CONTROL STATION | 04-149-2(P) | MORIAH Wind | Wind Speed & Direction, Crosswind/Headwind |
| CATOFF2 EMERGENCY CONTROL STA | 04-74-1(S) | ALRCS | Launch Info |
| CATOFF2 EMERGENCY CONTROL STA | 04-74-1(S) | MORIAH Wind | Wind Speed & Direction, Crosswind/Headwind |
| CC CAT1 | | ALRCS | Launch Info |
| CC CAT1 | 03-79-9-Q | MORIAH Wind | Wind Speed & Direction |

| WORK CENTER (USER) | | | |
|---|---|---|---|
| IDENTIFICATION | LOCATION (CVN68 class) | SYSTEM / Application | LABEL (Data / Data Blocks) |
| CC CAT2 | | ALRCS | Launch Info |
| CC CAT2 | 03-69-4-Q | MORIAH Wind | Wind Speed & Direction |
| CC CAT3 | | ALRCS | Launch Info |
| CC CAT3 | 03-148-8-Q | MORIAH Wind | Wind Speed & Direction |
| CC CAT4 | | ALRCS | Launch Info |
| CC CAT4 | 03-161-2-Q | MORIAH Wind | Wind Speed & Direction |
| CDC | 03-156-0 | ISIS | Air Plan |
| CDC | 03-156-0 | ISIS | Airborne tanker status |
| CDC | 03-156-0 | ISIS | Aircraft Status (Deck) |
| CDC | 03-156-0 | ISIS | Alert Aircraft Status |
| CDC | 03-156-0 | ISIS | ALRE Status |
| CDC | 03-156-0 | ISIS | ASW Datum |
| CDC | 03-156-0 | ISIS | Bingo Fuels |
| CDC | 03-156-0 | ISIS | Charts / Maps |
| CDC | 03-156-0 | ISIS | Communication Plan |
| CDC | 03-156-0 | ISIS | Current Ship's position |
| CDC | 03-156-0 | ISIS | Current Ship's Weather |
| CDC | 03-156-0 | ISIS | Daily Call Signs |
| CDC | 03-156-0 | ISIS | Divert Field Info |
| CDC | 03-156-0 | ISIS | Equip (radar) status |
| CDC | 03-156-0 | ISIS | Event Information |
| CDC | 03-156-0 | ISIS | Event Information |
| CDC | 03-156-0 | ISIS | Helo Status |
| CDC | 03-156-0 | ISIS | Plane Guard Ship |
| CDC | 03-156-0 | ISIS | Recovery Video |
| CDC | 03-156-0 | ISIS | Ship's PIM |
| CDC | 03-160-0 | MORIAH Wind | Wind Speed & Direction |
| CDC Electric Warfare Area | 03-165-1 | MORIAH Wind | Wind Speed & Direction |
| Damage Control | ? | AWIMS | Weight Report |
| FDC | 04-160-1 | AWIMS | Bomb Farm Log |
| FDC | 04-160-1 | AWIMS | On Load & Flow Sheet |
| FDC | 04-160-1 | AWIMS | Weapons Location on Flight Deck/Hangar Deck |
| FDC | 04-160-1 | ISIS | Air Plan |
| FDC | 04-160-1 | ISIS | Airborne Tanker Status |
| FDC | 04-160-1 | ISIS | Aircraft Bulletin |
| FDC | 04-160-1 | ISIS | Aircraft Status (Deck) |
| FDC | 04-160-1 | ISIS | Aircraft Weight |
| FDC | 04-160-1 | ISIS | Alert Aircraft Status |
| FDC | 04-160-1 | ISIS | Event Information |
| FDC | 04-160-1 | ISIS | Event Information |
| FDC | 04-160-1 | ISIS | Recovery Video |
| FDC | 04-160-1 | ISIS | Weapons Information |
| FDC | 04-160-1 | ISIS | Wind Information |
| FDC | 04-160-1 | ISIS / ALRCS | ALRE Status |
| FLAG BRIDGE/PLOT | 07-159-1-C | ISIS | Event Information |

| WORK CENTER (USER) | | | |
|---|---|---|---|
| IDENTIFICATION | LOCATION (CVN68 class) | SYSTEM / Application | LABEL (Data / Data Blocks) |
| FLAG BRIDGE/PLOT | 07-159-1-C | MORIAH Wind | Wind Speed & Direction |
| FOSAMS/ROLMS | 02-84-P | AWIMS | Weapons information |
| G1 WORKCENTER | 1-133-4-A | AWIMS | G1 Build Sheet |
| G1 WORKCENTER | 1-133-4-A | AWIMS | G1 Magazine Temp Log |
| G1 WORKCENTER | 1-133-4-A | AWIMS | G1 Re-stow Sheet |
| G1 WORKCENTER | 1-133-4-A | AWIMS | On Load & Flow Sheet |
| G1 WORKCENTER | 1-133-4-A | ISIS | Event Information |
| G2 Division Work Center | 3-82-2-Q | AWIMS | G2 Build Sheet |
| G2 Division Work Center | 3-82-2-Q | AWIMS | G2 Magazine Temp Log |
| G2 Division Work Center | 3-82-2-Q | AWIMS | G2 Re-stow Sheet |
| G2 Division Work Center | 3-82-2-Q | AWIMS | On Load & Flow Sheet |
| G2 Division Work Center | 3-82-2-Q | ISIS | Event Information |
| G-3 Division Office (FWD) | 2-54-4-Q | AWIMS | G3 Build Sheet |
| G-3 Division Office (FWD) | 2-54-4-Q | AWIMS | G3 Magazine Temp Log |
| G-3 Division Office (FWD) | 2-54-4-Q | AWIMS | G3 Re-stow Sheet |
| G-3 Division Office (FWD) | 2-54-4-Q | AWIMS | Magazine Arrangement |
| G-3 Division Office (FWD) | 2-54-4-Q | AWIMS | Mission Load List |
| G-3 Division Office (FWD) | 2-54-4-Q | AWIMS | Status Board |
| G-3 Division Office (FWD) | 2-54-4-Q | ISIS | Event Information |
| G-3 Division Office (AFT) | 3-143-3-Q | AWIMS | On load & Flow Sheet |
| G-3 Division Office (AFT) | 3-143-3-Q | ISIS | Event Information |
| G4 Division Work Center | 02-170-1-L | AWIMS | On load & Flow Sheet |
| G4 Division Work Center | 02-170-1-L | ISIS | Event Information |
| G-5 Inventory Accounting | 02-64-4-Q | AWIMS | Mission Load List |
| G-5 Inventory Accounting | 02-64-4-Q | AWIMS | Weapons inventory/info |
| G-5 Inventory Accounting | 02-64-4-Q | ISIS | Event Information |
| HDC | 1-94-S | AWIMS | Bomb Farm Log |
| HDC | 1-94-S | AWIMS | On Load & Flow Sheet |
| HDC | 1-94-S | AWIMS | Weapons Location on Flight Deck/Hangar Deck |
| HDC | 1-94-S | ISIS | Air Plan |
| HDC | 1-94-S | ISIS | Airborne tanker status |
| HDC | 1-94-S | ISIS | Aircraft Status (Deck) |
| HDC | 1-94-S | ISIS | Aircraft Weight |
| HDC | 1-94-S | ISIS | Alert Aircraft Status |
| HDC | 1-94-S | ISIS | Event Information |
| HDC | 1-94-S | ISIS | Event Information |
| HDC | 1-94-S | ISIS | Recovery Video |
| HDC | 1-94-S | ISIS | Weapons information |
| HDC | 1-94-S | ISIS / ALRCS | ALRE Status |
| ICCS 1&2 | 03-70-1-Q | ALRCS | Aircraft Bulletins |
| ICCS 1&2 | 03-70-1-Q | ALRCS | ALRE Status/Information |
| ICCS 1&2 | 03-138-2 | ISIS | Aircraft Weight |
| ICCS 1&2 | 03-70-1-Q | ISIS | Event Information |
| ICCS 1&2 | 03-70-1-Q | MORIAH Wind | Head/Cross Wind, Wind Speed & Direction |

| WORK CENTER (USER) | | | |
|---|---|---|---|
| IDENTIFICATION | LOCATION (CVN68 class) | SYSTEM / Application | LABEL (Data / Data Blocks) |
| ICCS 3&4 | 03-148-8-Q | ALRCS | Aircraft Bulletins |
| ICCS 3&4 | 03-148-8-Q | ALRCS | ALRE Status/Information |
| ICCS 3&4 | 03-138-2 | ISIS | Aircraft Weight |
| ICCS 3&4 | 03-148-8-Q | ISIS | Event Information |
| ICCS 3&4 | 03-148-8-Q | MORIAH Wind | Head/Cross Wind, Wind Speed & Direction |
| LENS RM | 03-123-10 | ECSS | Basic Angle |
| LENS RM | 010-160-1 | IFLOLS | Air Officer Interlock Status |
| LENS RM | 03-123-10 | IFLOLS | Aircraft Hook to Eye |
| LENS RM | 03-123-10 | IFLOLS | Aircraft Type |
| LENS RM | 03-123-10 | IFLOLS | Barricade On Indicator |
| LENS RM | 03-123-10 | IFLOLS | Basic Angle |
| LENS RM | 03-123-10 | IFLOLS | Brightness Reset |
| LENS RM | 03-123-10 | IFLOLS | Datum/Wave Off/Cut Light Intensity |
| LENS RM | 03-123-10 | IFLOLS | Ship Navigation Information |
| LENS RM | 03-123-10 | IFLOLS | Source Light Intensity |
| LENS RM | 03-123-10 | IFLOLS | SPN-46 Heave |
| LENS RM | 03-123-10 | IFLOLS | SPN-46 Pitch |
| LENS RM | 03-123-10 | IFLOLS | SPN-46 Roll |
| LENS RM | 03-123-10 | IFLOLS | Stabilization Mode |
| LENS RM | 03-123-10 | IFLOLS | Wave Off |
| LENS RM | 03-123-10 | IFLOLS | Wave Off |
| LENS RM | 03-123-10 | ILARTS | Cut |
| LENS RM | 03-123-10 | ILARTS | Wave Off |
| LENS RM | 03-123-10 | MOVLAS | Cut |
| LENS RM | 03-123-10 | MOVLAS | Wave Off |
| LENS RM | 03-123-10 | VISUAL | Ship Navigation Information |
| LENS RM | 03-123-10 | VISUAL | Wind Speed & Direction |
| LSO | 04-231-0 | VISUAL | Air Officer Interlock Status |
| LSO | 04-231-0 | VISUAL | Aircraft Hook to Eye |
| LSO | 04-231-0 | VISUAL | Aircraft Type |
| LSO | 04-231-0 | VISUAL | Barricade On Indicator |
| LSO | 04-231-0 | VISUAL | Basic Angle |
| LSO | 04-231-0 | VISUAL | Cut light Indicator |
| LSO | 04-231-0 | VISUAL | Failure Mode |
| LSO | 04-231-0 | VISUAL | GO/NO GO |
| LSO | 04-231-0 | VISUAL | Hook to Ramp alarm |
| LSO | 04-231-0 | VISUAL | Hook to Ramp Warning |
| LSO | 04-231-0 | VISUAL | Low Cell Flash Rate |
| LSO | 04-231-0 | VISUAL | Low Cell Intensity |
| LSO | 04-231-0 | VISUAL | Power "on" |
| LSO | 04-231-0 | VISUAL | Ship List Information |
| LSO | 04-231-0 | VISUAL | Ship Trim Information |
| LSO | 04-231-0 | VISUAL | Source Light Intensity |
| LSO | 04-231-0 | VISUAL | Stabilization Mode |
| LSO | 04-231-0 | VISUAL | Targeted Wire # / HTD |

| WORK CENTER (USER) | | | |
|---|---|---|---|
| IDENTIFICATION | LOCATION (CVN68 class) | SYSTEM / Application | LABEL (Data / Data Blocks) |
| LSO | 04-231-0 | VISUAL | Wave Off Indicator |
| LSO | 04-231-0 | VISUAL | Wave Off Location |
| ~~LSO~~ | ~~04-231-0~~ | ~~ISIS~~ | ~~ALRE Status~~ |
| LSO | 04-231-0 | VISUAL | Event Information |
| LSO | 04-231-0 | ISIS | Event Information |
| LSO | 04-231-0 | ISIS | Pilot Qualifications/Grades |
| LSO | 04-231-0 | VISUAL* | Recovery Video |
| ~~LSO~~ | ~~04-231-0~~ | ~~ISIS~~ | ~~SPN-46 info~~ |
| LSO | 04-231-0 | VISUAL | A/C DRIFT RATE |
| LSO | 04-231-0 | VISUAL | A/C IDENT |
| LSO | 04-231-0 | VISUAL | A/C RANGE |
| LSO | 04-231-0 | VISUAL | A/C SINK RATE |
| LSO | 04-231-0 | VISUAL | A/C SPEED |
| LSO | 04-231-0 | VISUAL | ACLS LOCK ON |
| LSO | 04-231-0 | VISUAL | ACLS MODE |
| LSO | 04-231-0 | VISUAL | Aircraft Bulletins |
| LSO | 04-231-0 | VISUAL | CLR/FOUL DECK |
| LSO | 04-231-0 | VISUAL | Datum/Wave-Off/Cut Light Intensity |
| LSO | 04-231-0 | VISUAL | Deck Status Light |
| LSO | 04-231-0 | VISUAL | Hook To Ramp Motion |
| LSO | 04-231-0 | VISUAL | Hook Touch Down (A/C) |
| LSO | 04-231-0 | VISUAL | Ramp motion |
| LSO | 04-231-0 | VISUAL | Wave Off |
| LSO | 04-231-0 | VISUAL | Wave Off |
| LSO | 04-231-0 | VISUAL | Weather Information |
| LSO | 04-231-0 | VISUAL | Wind (Head & Cross) Angle |
| LSO | 04-231-0 | VISUAL | Mr. Hands Information |
| LSO Equipment Room | 03-233-2 | IFLOLS | Cut |
| LSO Equipment Room | 03-233-2 | IFLOLS | Wave Off |
| LSO Equipment Room | 03-233-2 | IFLOLS | Wave Off |
| LSO HUD | 04-231-0 | LSO HUD | Wind Speed & Direction |
| Main Comm | 03-108-0 | ISIS | Air Plan |
| Main Comm | 03-108-0 | ISIS | Current Ship's Weather |
| Main Comm | 03-108-0 | ISIS | Event Information |
| Main Comm | 03-108-0 | ISIS | Event Information |
| METOC | 06-160-3 | Moriah | Ship Navigation Information |
| METOC | 06-160-3 | MORIAH Wind | Wind Speed & Direction |
| Pilot House | 09-160-1 | ISIS | Air Plan |
| Pilot House | 09-160-1 | ISIS | Airborne tanker status |
| Pilot House | 09-160-1 | ISIS | Aircraft Bulletins |
| Pilot House | 09-160-1 | ISIS | Aircraft Status (Deck) |
| Pilot House | 09-160-1 | ISIS | Aircraft Weight |
| Pilot House | 09-160-1 | ISIS | Alert Aircraft Status |
| Pilot House | 09-160-1 | ISIS | ALRE Status |
| Pilot House | 09-160-1 | ISIS | ASW Datum |

| WORK CENTER (USER) | | | |
|---|---|---|---|
| IDENTIFICATION | LOCATION (CVN68 class) | SYSTEM / Application | LABEL (Data / Data Blocks) |
| Pilot House | 09-160-1 | ISIS | Bingo Fuels |
| Pilot House | 09-160-1 | ISIS | Current Ship's Position |
| Pilot House | 09-160-1 | ISIS | Current Ship's Weather |
| Pilot House | 09-160-1 | ISIS | Daily Call Signs |
| Pilot House | 09-160-1 | ISIS | Divert Field Info |
| Pilot House | 09-160-1 | ISIS | Event Information |
| Pilot House | 09-160-1 | ISIS | Event Information |
| Pilot House | 09-160-1 | ISIS | Helo Status |
| Pilot House | 09-160-1 | ISIS | Pilot qualifications/grades |
| Pilot House | 09-160-1 | ISIS | Plane Guard Ship |
| Pilot House | 09-160-1 | ISIS | Recovery Video |
| Pilot House | 09-160-1 | ISIS | SPN-46 info |
| Pilot House | 09-160-1 | ISIS | Tanker/Helo status (Deck) |
| Pilot House | 09-160-1 | MORIAH Wind | Wind Speed & Direction |
| PRI-FLY | 010-160-1 | AWIMS | On Load & Flow Sheet |
| PRI-FLY | 010-160-1 | IFLOLS | Aircraft Hook to Eye |
| PRI-FLY | 010-160-1 | IFLOLS | Aircraft Type |
| PRI-FLY | 010-160-1 | IFLOLS | Barricade On Indicator |
| PRI-FLY | 010-160-1 | IFLOLS | Basic Angle |
| PRI-FLY | 010-160-1 | IFLOLS | Brightness Reset |
| PRI-FLY | 010-160-1 | IFLOLS | Cut light Indicator |
| PRI-FLY | 010-160-1 | IFLOLS | Datum/Wave-off/Cut Light Intensity |
| PRI-FLY | 010-160-1 | IFLOLS | Failure Mode |
| PRI-FLY | 010-160-1 | IFLOLS | GO/NO GO |
| PRI-FLY | 010-160-1 | IFLOLS | Hook to Ramp Meter - Dynamic |
| PRI-FLY | 010-160-1 | IFLOLS | Hook to Ramp Meter - static |
| PRI-FLY | 010-160-1 | IFLOLS | Hook to Ramp Warning |
| PRI-FLY | 010-160-1 | IFLOLS | Hook Touchdown meter - dynamic |
| PRI-FLY | 010-160-1 | IFLOLS | Hook Touchdown meter - static |
| PRI-FLY | 010-160-1 | IFLOLS | Low Cell Flash Rate |
| PRI-FLY | 010-160-1 | IFLOLS | Low Cell Intensity |
| PRI-FLY | 010-160-1 | IFLOLS | Power "on" |
| PRI-FLY | 010-160-1 | IFLOLS | PRI-FLY / Lens Room. Cmd. |
| PRI-FLY | 010-160-1 | IFLOLS | Ship List Information |
| PRI-FLY | 010-160-1 | IFLOLS | Ship Trim Information |
| PRI-FLY | 010-160-1 | IFLOLS | Source Light Intensity |
| PRI-FLY | 010-160-1 | IFLOLS | Stabilization Mode |
| PRI-FLY | 010-160-1 | IFLOLS | Targeted Wire # / HTD |
| PRI-FLY | 010-160-1 | IFLOLS | Wave Off Indicator |
| PRI-FLY | 010-160-1 | IFLOLS | Wave Off |
| PRI-FLY | 010-160-1 | IFLOLS | Wave Off Location |
| PRI-FLY | 010-160-1 | ISIS | Air Plan |
| PRI-FLY | 010-160-1 | ISIS | Airborne tanker status |

| WORK CENTER (USER) | | | |
|---|---|---|---|
| IDENTIFICATION | LOCATION (CVN68 class) | SYSTEM / Application | LABEL (Data / Data Blocks) |
| PRI-FLY | 010-160-1 | ISIS | Aircraft Bulletins |
| PRI-FLY | 010-160-1 | ISIS | Aircraft Status (Deck) |
| PRI-FLY | 010-160-1 | ISIS | Aircraft Weight |
| PRI-FLY | 010-160-1 | ISIS | Alert Aircraft Status |
| PRI-FLY | 010-160-1 | ISIS | ALRE Status |
| PRI-FLY | 010-160-1 | ISIS | ASW Datum |
| PRI-FLY | 010-160-1 | ISIS | Bingo Fuels |
| PRI-FLY | 010-160-1 | ISIS | Current Ship's Position |
| PRI-FLY | 010-160-1 | ISIS | Current Ship's Weather |
| PRI-FLY | 010-160-1 | ISIS | Daily Call Signs |
| PRI-FLY | 010-160-1 | ISIS | Divert Field Info |
| PRI-FLY | 010-160-1 | ISIS | Event Information |
| PRI-FLY | 010-160-1 | ISIS | Event Information |
| PRI-FLY | 010-160-1 | ISIS | Helo Status |
| PRI-FLY | 010-160-1 | ISIS | Pilot qualifications/grades |
| PRI-FLY | 010-160-1 | ISIS | Plane Guard Ship |
| PRI-FLY | 010-160-1 | ISIS | Recovery Video |
| PRI-FLY | 010-160-1 | ISIS | SPN-46 info |
| PRI-FLY | 010-160-1 | ISIS | Tanker/Helo status (Deck) |
| PRI-FLY | 010-160-1 | MORIAH Wind | Wind Speed |
| Ready Room/MC | 03-220/50 -0 | AWIMS | Mission Load List |
| Ready Room/MC | 03-220/50 -0 | AWIMS | Weapons Information |
| Ready Room/MC | 03-220/50 -0 | ISIS | Air Plan |
| Ready Room/MC | 03-220/50 -0 | ISIS | Airborne Tanker Status |
| Ready Room/MC | 03-220/50 -0 | ISIS | Aircraft Status (Deck) |
| Ready Room/MC | 03-220/50 -0 | ISIS | Aircraft Weight |
| Ready Room/MC | 03-220/50 -0 | ISIS | Alert Aircraft Status |
| Ready Room/MC | 03-220/50 -0 | ISIS | ASW Datum |
| Ready Room/MC | 03-220/50 -0 | ISIS | Bingo Fuels |
| Ready Room/MC | 03-220/50 -0 | ISIS | Charts / Maps |
| Ready Room/MC | 03-220/50 -0 | ISIS | Current Ship's position |
| Ready Room/MC | 03-220/50 -0 | ISIS | Current Ship's Weather |
| Ready Room/MC | 03-220/50 -0 | ISIS | Divert Aircraft Status |
| Ready Room/MC | 03-220/50 -0 | ISIS | Divert Field Info |
| Ready Room/MC | 03-220/50 -0 | ISIS | Event Information |
| Ready Room/MC | 03-220/50 -0 | ISIS | Event Information |
| Ready Room/MC | 03-220/50 -0 | ISIS | Helo Status |
| Ready Room/MC | 03-220/50 -0 | ISIS | Pilot Qualifications/Grades |
| Ready Room/MC | 03-220/50 -0 | ISIS | Plane Guard Ship |
| Ready Room/MC | 03-220/50 -0 | ISIS | Recovery Video |
| Ready Room/MC | 03-220/50 -0 | ISIS | Ship's PIM |
| Ready Room/MC | 03-220/50 -0 | ISIS | Tanker/Helo status (Deck) |
| Ready Room/MC | 03-220/50 -0 | ISIS | Wind Over Deck |
| SEC CONN Station | 4-124-1-C | MORIAH Wind | Wind Speed & Direction |
| SPN46 | 07-175-3 | SPN-46 | Wind Speed & Direction |

| WORK CENTER (USER) | | | |
|---|---|---|---|
| IDENTIFICATION | LOCATION (CVN68 class) | SYSTEM / Application | LABEL (Data / Data Blocks) |
| SPN-46 | 07-175-3 | SPN-46 | Basic Angle (IFLOLS) |
| SPN-46 | 07-175-3 | SPN-46 | Ship Navigation Information |
| SPN-46 | 07-175-3 | SPN-46 | VISUAL Tracking Data |
| SPN-46 | 07-175-3 | SPN-46 | Wave-off |
| Strike Ops | 03-138-1 | AWIMS | Mission Load List |
| Strike Ops | 03-138-1 | ISIS | Air Plan |
| Strike Ops | 03-138-1 | ISIS | Aircraft Status (Deck) |
| Strike Ops | 03-138-1 | ISIS | ALRE Status |
| Strike Ops | 03-138-1 | ISIS | Divert Field Info |
| Strike Ops | 03-138-1 | ISIS | Event Information |
| Strike Ops | 03-138-1 | ISIS | Ship's PIM |
| Strike Ops | 03-138-1 | ISIS | Weapons information |
| Tactical Operations Plot | 09-162-1 | MORIAH Wind | Wind Speed & Direction |
| TFCC | 03-150-0 | MORIAH Wind | Wind Speed & Direction |
| V-2 Division Office | 03-79-0 | ADMACS | Aircraft Bulletins |
| V-2 Division Office | 03-79-0 | ALRCS | ALRE Status/Information |
| V-2 Division Office | 03-79-0 | ISIS | Event Information |
| V-2 Maintenance Office | 03-79-0 | ADMACS | Aircraft Bulletins |
| V-2 Maintenance Office | 03-79-0 | ALRCS | ALRE Status/Information |
| V-2 Maintenance Office | 03-79-0 | ISIS | Event Information |
| V-4 Division Office | 02-79-P | ALRCS | ALRE Status/Information |
| V-4 Division Office | 02-79-P | ISIS | Event Information |
| WPNS DEPT CC | 02-165-2-Q | AWIMS | On Load & Flow Sheet |
| WPNS DEPT CC | 02-165-2-Q | ISIS | Event Information |

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# APPENDIX B: AIRCRAFT HANDLER’S QUESTIONNAIRE

1. Describe the most complex task you perform in the normal course of the day’s events.
2. Describe the most time consuming aspect of your job.
3. If you could automate specific portions of your job, what would you automate and to what degree. (List as many as you wish – prioritize them with 1 being the highest priority).
4. Are there aspects of your job that you feel should never be abandoned by “human intelligence”, i.e. which should never be automated? What are they and why is it they should be left as is?
5. Are there aspects of your job that you cannot spend adequate time on because of either time constraints or other extraneous constraints that keep you from them?
6. Would a decision support system that is able to display a “Spot Plan” given the air plan requirements, the aircraft availability, weapons load, etc. be a welcomed “tool”, or would you view this as a threat to your job? If it were perceived as a threat, what would make it less threatening in your eyes?
7. In the planning stages of preparing for a specific launch (first go, second go, third go), are there redundant tasks that could be automated?
8. What specific inputs should be taken into consideration?
9. For display purposes, is a color display preferred over monochrome?
10. Who else would you want to have input to this effort to digitize the Ouija board?
11. To what extent would you want their input?
12. Are their specific questions or inputs that we should ask of them?
13. Are their other inputs that you would like to provide us with?
14. Are their specific Handlers (current or otherwise) that you would recommend we survey (Please provide information to help us locate them, e.g. Command Name or e-mail address)?

15. Rate the functionality of the following hardware in support of handling aircraft:

| *Rate 1 to 5* *(5 is Excellent, 1 is Very Poor)* | **Maintenance Control** | **Ready Room** | **Bridge** | **Air Boss** | **Flight Deck Control** | **Flight Deck** | **Hangar Deck** |
|---|---|---|---|---|---|---|---|
| Hand held devices (PDAs) | | | | | | | |
| Wearable computers | | | | | | | |
| Heads-up displays (on Yellow Shirts, Blue Shirts, etc.) | | | | | | | |
| Touch screen displays | | | | | | | |
| Pen tablets | | | | | | | |
| Hands-free computing | | | | | | | |
| Virtual Displays (3D graphic representation of objects and environment) | | | | | | | |

# APPENDIX C: RESULTS OF QUESTIONNAIRE

**From CVN-73 Handler**

1. Display positions of JBD, bomb/missile elevators, whip antennae, and elevators.

2. Generate statistics per pilot (an aircraft's pilot can be retrieved from ISIS) like flying time, recoveries by arresting wire number, aircraft maintenance.

3. Generate statistics per shipboard personnel (time per wash down, fueling/de-fueling efficiencies).

4. Generate statistics per aircraft like time to launch, counts by arresting wire number, wash-downs, down rate, de-fuels.

5. Generate statistics per ship like sortie rate.

6. Optimize aircraft re-spots.

7. Perform support functions (like Maximum Spotting Density for the Spotting Room).

8. Mobilize the Ouija board so that anyone on the ship's LAN can visualize info and/or the Handler can generate the next day's spotting configurations from the head, his stateroom, or the beach.

9. Zoom in on digital sections of the flight deck. The colored aircraft templates currently used would be replaced by vector (CAD like) drawings that allow highly accurate investigations of spotting configurations.

10. Select a camera and display what it is seeing.

11. Zoom in on a subsection.

12. Digital enhancement of the video (sharpening, contrast enhancement) under user control.

13. Touch a camera icon then an aircraft to automatically bring up video and zoom (you won't have to specify a camera and touch out the zoom region).

14. Store all aircraft movements for an entire cruise. These could be searched (for F18 bow re-spots at night), replayed with VCR-like controls (fast forward, reverse, pause), and saved.

15. Panoramic view (digitally create an image mosaic of the entire flight or hangar deck). This may have some problems because not all cameras will have the same viewing position. For example, the Aft Radar Mast Camera will be around 150' aft of the island cameras and at lower elevation. The mosaic may be strange. We could patch together a single image on the next cruise to give Handlers an idea.

16. Emergency video recording. In case of an emergency (or for training), the computer could start archiving a camera's imagery (or subsection). I would guess you could only save 5 to 10 minutes before hard drives filled up. Alternatively, you could have a standby recorder co-located with the workstation and clicking an option would save imagery to a SVHS tape with hours of storage potential.

17. Count the elevator runs (from Mr. Husni's kickoff meeting notes).

18. Count the aircraft moves (from Mr. Husni's kickoff meeting notes).

19. Render the decks with holographs (the Navy has been researching washtub-like rendering displays for years) so that everything appears in 3D.

20. Retrieve video snippets from a ship’s cruise (e.g. “Show me all of 105’s nighttime recoveries.”). The degree of automation would be contingent on what equipment you buy and how you hook it up. For example, EATS will automatically be able to print out a list for the above without any additional equipment. You could then walk to the PLAT camera room and try to retrieve the video from their circular storage system (a drawer of tapes with the last – or most recent - tape put in being the last to be reused). This would be pretty onerous because of the manual review of many tapes but the timestamps are on the tapes. Alternatively, EATS video could be streamed to a bank of tape decks. This gives EATS more control of the imagery and potentially allows EATS to automatically generate one tape from its list of “interesting events” and extraction of video data from banks of decks through digital control.

21. Digital storage of “interesting events.” A user (from Pri-fly or a training air space, etc…) could say “Log all recoveries for 310.” EATS would then temporarily store each recovery and upon finding out that the recovered aircraft (from ISIS) was 310, would stream the data onto the network to the designated airspace. If it weren’t 310, EATS would write over the data. I don’t know how maintenance works but I would think this may be handy where something on an aircraft was suspicious and they might want to review it in slow-motion when they had time (like a faulty aileron).

22. EATS could allow the zoom-in, observation, and tracking of personnel.

23. EATS may allow some gross form of FOD detection.

24. EATS may allow some gross form of ordnance inspection.

25. Fouled deck detection (in addition to numerous others).

**From Commander Yoast, Aircraft Handler for CVN-73 and Aviation Bosun Mate Alan Procter**

Most tense movement is when a Deck Edge Elevator is down. It is very difficult because it involves coordination amongst so many spaces. Tension is up. 2 minutes after it is down, the operator will get a call from the bridge about when it can come up again. CCTV hangar bay cameras allow him to recall the elevator quickly. Two cameras have pan/tilt/zoom.

Joe Breslen Memorial Camera monitors the bow catapults so that when the ILARTS camera is switched to recoveries and the ship is still launching aircraft, something is recording that area. It is a low light level camera with a fixed aperture.

Another 360-degree camera (actually much less, probably 180) is used for spotting board operators (an Elevator Operator (EO)). AH can bring a guy down from the 08 level on the sound powered phones or from within the ILARTS booth down below and they just use the CCTV to spot ships. The camera has pan, tilt and zoom. This low light camera (not “Dage”, but off the shelf) must function with lots of glare in daytime but also work well at night. This might be fixed with a new monitor.

# APPENDIX D: INPUT/OUTPUT SURVEY

| **Flight Deck Control** | ADMACS | ISIS | Grumman | EATS |
|---|---|---|---|---|
| Support Equipment Status | | | | |
| Parking Plan / Spot Sheet | | | | |
| ALRE Equipment Status | | | | |
| Aircraft Position | | | | |
| | | | | |
| **CATTC / Primary Flight Control** | ADMACS | ISIS | Grumman | EATS |
| A/C Bingo Performance Data | | | | |
| External Flight Information (NOTAMS, etc.) | | | | |
| Operation Area Information | | | | |
| Bingo Field Information | | | | |
| CATCC Status Board | | | | |
| Primary Flight Control Status Board | | | | |
| | | | | |
| V-4 / Fuels Division | ADMACS | ISIS | Grumman | EATS |
| Total Fuel System Status | | | | |
| A/C Fueling Status | | | | |
| Fuel Crew Management | | | | |
| Fuel Station Status | | | | |
| Fuel Plan | | | | |
| | | | | |

| Squadron Operations | ADMACS | ISIS | Grumman | EATS |
|---|---|---|---|---|
| Squadron Plan of the Day (POD) | | | | |
| Pilot Qualifications | | | | |
| Squadron Duty Roster | | | | |
| Pilot Medical Status | | | | |
| Pilot Landing Grades | | | | |
| Squadron Training Plan | | | | |
| Squadron Flight Schedule | | | | |
| | | | | |
| CAG Operations | ADMACS | ISIS | Grumman | EATS |
| Aircraft Performance Parameters | | | | |
| Air Wing Tactics | | | | |
| Rules of Engagement | | | | |
| Threat Intelligence | | | | |
| Target / Op Area Information (Maps, coordinates, etc) | | | | |
| Target Photos | | | | |
| Strike Plan | | | | |
| | | | | |
| **Squadron Maintenance (Repeated for each squadron)** | ADMACS | ISIS | Grumman | EATS |
| Squadron Maintenance Plan | | | | |
| Squadron Flight Hour Records | | | | |
| Aircraft Maintenance Records | | | | |

| | | | | |
|---|---|---|---|---|
| (VIDS/MAFS) | | | | |
| Air Wing Aircraft Status Board (not replicated at Squadron Level) | | | | |
| | | | | |
| **Weapons Department** | **ADMACS** | **ISIS** | **Grumman** | **EATS** |
| Replenishment Requirements | | | | |
| Replenishment Planning | | | | |
| Magazine Inventory | | | | |
| Movement Plan | | | | |
| Build Plan | | | | |
| Break Out Plan | | | | |
| Load Plan | | | | |
| | | | | |
| **Combat Systems / C4I** | **ADMACS** | **ISIS** | **Grumman** | **EATS** |
| Recent Intelligence | | | | |
| SD Weapons and Status | | | | |
| Friendly Track Data | | | | |
| Hostile Track Data | | | | |
| OP Area Maps / Data | | | | |
| CDC/E-2 Status / Situation Displays | | | | |

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# APPENDIX E: RESPONSE TO INPUT/OUTPUT SURVEY

Response from CWO2 David Young, youngd@kitty-Hawk.navy.mil; COMM: 243-4295, X-6540 Fuels Maintenance Officer CV63.

| ***V-4 / Fuels Division*** | | **Others** |
|---|---|---|
| 11 | Total Fuel System Status | 8 O'clock reports |
| 12 | A/C Fueling Status | Checker Cards And Log Sheets Are Used To Track A/C Start Loads and Top Off Loads. We Use This Information To Track Each Individual Aircraft Fuel Issue. |
| 13 | Fuel Crew Management | COMNAVAIRPAC/COMNAVAIRLANT Instruction 3500.71a |
| 14 | Fuel Station Status | F/D Repair Personnel Physically Check During R-42/44 PMS Check. Use 8 O'clock Reports And Division Fuel Station Status Report To Track Status. |
| 15 | Fuel Plan | Use Air Plan For Fuel Load Of Aircraft. Use AFOSS To Plan For Fuel UNREPS. |

Response from LCDR Michael Shults [mshult@lincoln.navy.mil], Ordnance Handling Officer (OHO) for CVN-72

| ***Weapons Department*** | | **Others** |
|---|---|---|
| 34 | Replenishment Requirements | ROLMS/E-mail inputs to LOG REC |
| 35 | Replenishment Planning | ROLMS/E-mail |
| 36 | Magazine Inventory | ROLMS |
| 37 | Movement Plan | NONE- coordinated by Ordnance control, Ordnance Handling Officer (OHO) |
| 38 | Build Plan | None- coordinated by Ordnance control, OHO |
| 39 | Break Out Plan | None- coordinated by Ordnance control, OHO |

| | | |
|---|---|---|
| 40 | Load Plan | In puts provided to Strike Ops by phone or in person/E-mail. |

# APPENDIX F: ADMACS DEPLOYMENT PLAN[55]

| ACTIVITY | PROCUREMENT | INSTALLATION |
|---|---|---|
| CV 63 USS Kitty Hawk | FY02 | FY03 |
| CVN 65 USS Enterprise | FY01 | FY02 |
| CV 67 USS John F. Kennedy | FY02 | FY03 |
| CVN 68 USS Nimitz | FY98 | FY00 |
| CVN 69 USS Dwight D. Eisenhower | FY00 | FY02 |
| CVN 70 USS Carl Vinson | FY01 | FY02 |
| CVN 71 USS Theodore Roosevelt | FY01 | FY02 |
| CVN 72 USS Abraham Lincoln | FY00 | FY01 |
| CVN 73 USS George Washington | FY00 | FY01 |
| CVN 74 USS John C. Stennis | FY00 | FY01 |
| CVN 75 USS Harry S. Truman | FY00 | FY01 |
| CVN 76 USS Ronald Reagan | FY00 | FY01 |

55 N78-NTSP-A-50-0009/D, Navy Training System Plan For The Aviation Data Management And Control System, March 2001

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